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Linearly Stressed To Death: Consideration Of Early Childhood Stress As A Main Contributor To The Regional Variability In Classic Maya Mortuary Profiles

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LINEARLY STRESSED TO DEATH: CONSIDERATION OF EARLY CHILDHOOD STRESS AS A MAIN CONTRIBUTOR TO THE REGIONAL VARIABILITY IN CLASSIC MAYA MORTUARY PROFILES

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ABSTRACT

The Late and Terminal Classic periods were times of great social, economic, and political change in Maya civilization. Scholars have suggested that increasing levels of dietary stress during this time may have been the result of ecological instability, drought, warfare, and significant levels of population movement across the Maya lowlands. All of these processes may have affected human health and left measurable markers of stress in human skeletal material. The burial population recovered from two sites on Ambergris Caye, located near the coast of Belize, have significantly more sub-adult individuals than sites in inland Belize, such as Actuncan, suggesting the populations were differentially affected or had different cultural mechanisms to buffer threats to health. Macroscopic examination of non-occlusal surfaces was conducted on 206 teeth from a total of 67 individuals from the three sites. Both the age of occurrence and the number of stress episodes were compared using Student's t-Test to understand variability on a regional scale. Significant differences in the timing and frequency of early childhood stress episodes may account for the variance in mortuary profiles between the inland and island populations. The results show that more early childhood stress increases frailty within a population. However, early childhood stress cannot fully account for the differences in mortuary profiles.

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INTRODUCTION

Archaeological investigations suggest that sociopolitical instability during the Late (AD 600-800) and Terminal (AD 800-900) Classic periods may have resulted from overpopulation, environmental degradation, and warfare (Demarest 2004; Rice and Rice 2004; Sharer and Traxler 2006; Webster 2002). These changes culminated in the depopulation of Maya urban centers, referred to as the Maya collapse. By AD 900 nearly all centers in the Maya lowlands were abandoned. Any or all of these factors may contribute to an increase in stress, primarily in infants and children, which may leave observable markers on bones and teeth.

The prospects of an individual's health status and eventual mortality diminish greatly when exposed to early childhood stress (Cucina 2011:106). Early child hood stress may be defined as any significant stress episode, whether it be caused by illness or trauma, that occurs during the developmental stages of an individual's life. Juvenile stress provides the best possible inference for the determination of overall population health because juveniles and infants are physiologically weaker during dependence (Cucina 2004, 2011; Harvey 2010; Hillson 2002; Larson 2000, 2003; Wheeler 2009; Wright 1999). Subsequently, a higher incidence of non-specific stress markers will occur during this developmental stage of life. The occurrence of non-specific stressors, like linear enamel hypoplasia (LEH), disruptions in enamel formation caused by the visceral reaction to pressures on the immune system, are the best indicator of increased stress and can be scored based on severity, frequency, and time or age of occurrence. Study of LEH is preferred to other non-specific stress markers such as porotic hyperostosis and cribra orbitalia that occur on skeletal elements because enamel, unlike cortical and trabecular bone, does not remodel over time. Therefore, observable disruptions during enamel formation remain unchanged from the initial time of stress, leaving behind a permanent record of stress at a specific age that provides insight into the health and well-being of a population. Was there a significant difference in health and mortality among inland and island sites during the Classic period? This study assesses the influence of early childhood stress on frailty in two burial populations to address this question in the eastern Maya lowlands at the end of the Classic period.

The bioarchaeological approach is a valuable addition to understanding the archaeological record because it provides information on age, sex, and activity, as well as health and mortality. Distinct changes to skeletal morphology are caused by a number of variables, including environment, nutrition, infection, and workload stresses. These are typically referred to as non-specific stressors because they cannot always be differentiated due to the multiplicity of causal factors. Insults to skeletal elements attributed to dietary and environmental restrictions, as well as trauma due to violent conflict, are not always discernible. However, use of human dentition allows for more reliable study as it does not tooth enamel remodel and is less affected by taphonomic pressures than other skeletal elements. This study builds on previous dental analyses within the Maya lowlands. Mendez Colli et al. (2009), Andrea Cucina (2011), Lori Wright (1999) and colleagues used dental analysis of early childhood stress to assess not only temporal change, but also intra-site frailty pertaining to stress where poor preservation of skeletal elements would not allow. I draw from these methods to evaluate the effects of stress on mortality not only within the given sites, but across different environments within the Maya lowlands.

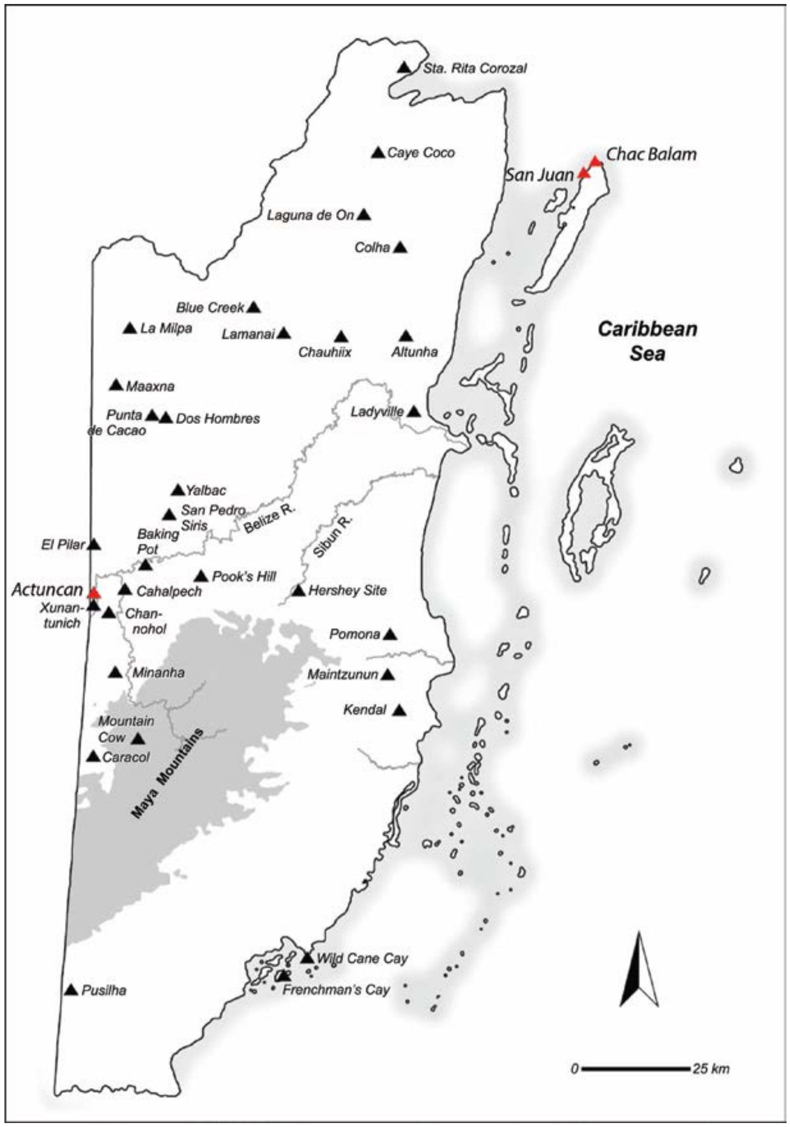

Figure 1: Map of archaeological sites in Belize (Adapted from Helmke C. 2011)

This study compares the health of two regions in the eastern Maya lowlands, the inland site of Actuncan (Figures 1 and 2) located in the Belize River Valley (BRV), and the island sites of San Juan and Chac Balam located on the northern portion of Ambergris Caye approximately 20 km from the eastern coast of Belize (Figure 3). Metric analysis of LEH present on the primary dentition in the burial populations of the three sites includes 42 individuals from Ambergris Caye and 25 individuals from Actuncan. Both collections are housed at the University of Mississippi.

The prevalence of non-specific stress indicators observable on the dental assemblage from individuals buried at these sites demonstrates potential differences in health between coastal and inland populations and is used to evaluate the relation to the mortality profiles of these burial populations. More broadly, this comparison is useful in reconstructing basic patterns of childhood and adult health for both regions.

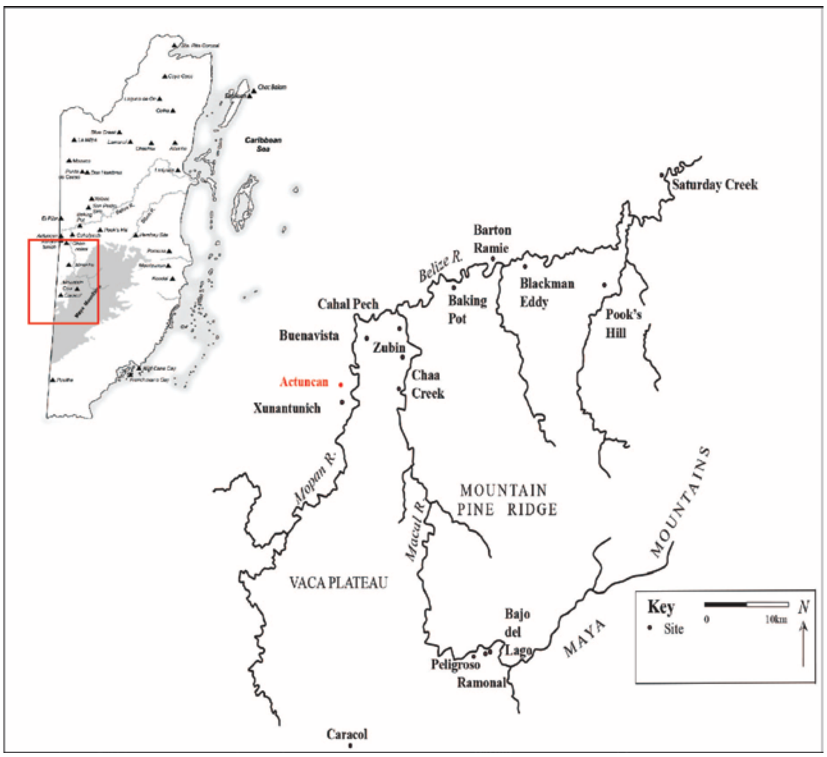

Figure 2: Map of Belize River Valley sites (Adapted from Freiwald 2011:5)

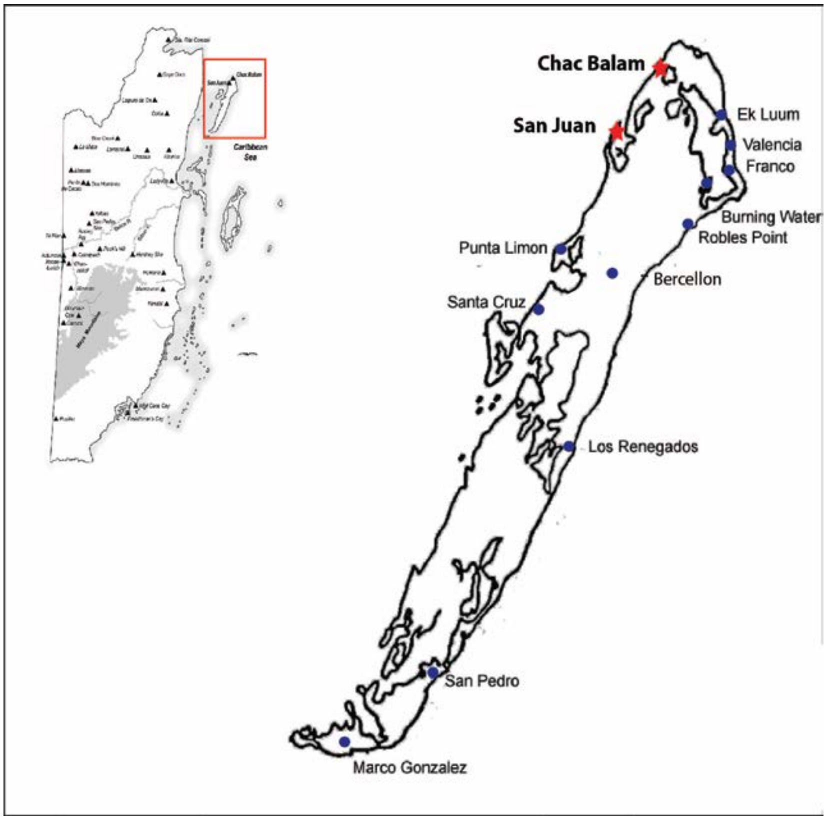

Figure 3: Map of Ambergris Caye sites (Adapted from Garber and Guderjan 1995)

Preliminary analysis of the Ambergris Caye burial populations shows a significantly higher proportion of juveniles (56%) than those reported in the upper Belize River valley, including the sites San Lorenzo (33%), Chaa Creek (7%), and Xunantunich (21%) (Adams 1998; Freiwald 2011; Guderjuan and Garber 1995; Song 1995). The burial population from Actuncan, located near these BRV centers, consists of 33.4% subadult remains. The burial population at Actuncan follows closely the other populations within the Maya lowlands, while the burial populations from the Ambergris Caye seem to have significantly more subadults. I analyze the timing and frequency of LEH occurrences to ascertain whether generalized heath patterns account for the significant difference observed in juvenile mortality.

Dr. David Glassman (1995) completed an osteological analysis of the human remains from Ambergris Caye and suggested that the population was healthier than that observed at other Maya sites. Garber and Glassman (1995, 1999) touch on the analysis of non-specific stress markers in their discussion of Ambergris health patterns, stating that the low incidence of stress observed affirms their belief that the Ambergris Caye population was in relatively good health. Their analysis notes few incidents of porotic hyperostosis and cribra orbitalia, pathologies that have been closely associated with dietary stress and vitamin deficiency. However, they provide no analysis or discussion for the presence or absence of LEH, a non-specific stressor also associated with nutritional deficiencies and stress (Garber 1999; Glassman 1995). My proposal includes a reevaluation of the Ambergris population with an emphasis on metric analysis of LEH. A similar analysis of Actuncan burials has been completed by Scopa-Kelso (2004) with the limited skeletal sample that was available at the time of her study. Since then, an additional 21 individuals have been recovered from Actuncan and have yet to undergo analysis.

Following a macroscopic identification of dental pathologies, I used metric analysis to determine the time of disruption based on the LEH location on the enamel. Goodman and Rose (1990) published this method, which has been used around the world with great success to compare contemporary and non-contemporary populations (Hillson 1996; Ritzman 2008; Wheeler 2009; Wright 1997). An approximate age of occurrence for the LEH can be determined by measuring the distance from cemento-enamel junction (CEJ) to the midline of disruption using sliding calipers. I used this technique to determine the age at which stress occurred within the populations and establish the relationship between the number of defects and the age at death. Quantitative analysis of non-specific stress occurrences allows for the reconstruction of dietary and early childhood stress present within the skeletal populations. I assessed the health history for each population as a whole by correlating these occurrences with the number of juveniles present within the burial populations from Actuncan and the Ambergris Caye following research of Cucina (2011) and Wright (1999). The results show that early childhood stress is inversely related to individual's age at death, and also demonstrate difference among inland and coastal populations. However, the data cannot currently be used to explain differences in the demographics of the burial populations, which are affected by many other cultural factors.

In sum, this project is a comparative analysis of heath between coastal and inland populations in Belize at the end of the Classic period. The focus on LEH stress markers in tooth enamel of these populations provides a basis for comparison of non-specific stresses during childhood regardless of the individual’s age at death. By establishing a mean age of disruption for enamel defects and comparing the number of incidents to the age at death within the population, we can further understand the impact of early childhood stress and its influence on frailty during older age. My results provide an enhanced understanding not only of regional variation of pathological stress, but also offer a new consideration of the influence of non-specific stressors in the examination of juvenile mortality during the Late and Terminal Classic periods.

II: THE CLASSIC MAYA

The Classic period spans AD 250 to AD 900 and is divided into three periods of florescence and decline (McKillop 2004). The Early Classic period lasted 300 years, from AD 250-550, and showed a rise in social stratification and the construction of major urban centers. Marked shifts in power and changing alliances resulted in a reorganization of sociopolitical hierarchies that ushered in the Late Classic period (AD 600-800), which is noted for large urban populations, a widespread shared elite material culture, and states with divine kings who carved their political victories and defeats into stone (Sharer and Traxler 2006). This network slowly began to dissolve by AD 800. Archaeological investigations suggest that sociopolitical instability during the Late and Terminal Classic periods may have resulted from overpopulation, environmental degradation, drought, and warfare (Demarest 2004; Hodell and Yaeger 2007; Rice and Rice 2004; Sharer and Traxler 2006; Webster 2002). These changes culminated in the depopulation of Maya urban centers, commonly referred to as the Maya collapse. By AD 900, nearly all centers in the Maya lowlands were abandoned.

This thesis does not look to test or confirm any particular theory as to how and why the Maya civilization collapsed, but instead focuses on how the biocultural approach can be used to examine health and well-being in burial populations and what these tell us about living ones (but see Wood et al. 1992. The chapter begins with an overview of health among the Maya at the end of the Classic period and then turns to an overview of ethnohistoric and ethnographic studies of funerary traditions and how they inform archaeological interpretations of Maya burials. Lastly, an examination of burial patterns in Belize at the coastal and inland sites in this study provides the background necessary to assess the differential impact of health patterns and funerary practices on the distinct demographic profiles of Actuncan, San Juan, and Chac Balam burial populations.

Maya Health in the Archaeological Record

Explanations of mortality and health profiles in some regions have relied on cultural ecological interpretations of subsistence patterns to explain declining health and increase dietary stress on Maya populations during the decades leading to the collapse (White 1997; Whittington and Reed 1997). Studies of Maya social complexity have shown a boom in population growth during the Classic period (AD 300-900) that reached its peak during the Late Classic period. McKillop (2004:169) cites Rice and Culbert's (1990) publication of Classic Maya demographics, which established estimates of change in population density through the Classic occupation within the Maya lowlands. Rice and Culbert’s (1990) estimates using patio structure expansion episodes at 15 sites within the region show that the population density during the Late and Terminal Classic grew to be twice that of the Early Classic occupation. Maya subsistence strategies, especially in the lowland region, relied heavily on maize agriculture, and with a population increase at that rate, it is theorized that agricultural production could not be sustained (White 1997; Whittington and Reed 1997:167).

Wright and White (1996:148) evaluated the early ecological explanation for the deterioration of Maya health in the Southern lowlands during the Classic period. The ecological model for collapse posited that there was an inability to maintain high levels of agricultural production needed to support growing populations. Swidden farming could not keep pace with increasing demands due to the degradation of agricultural fields from overuse and erosion. In addition, a lack of domesticated animals meant that Maya societies relied on wild game for protein, which may not have been available to all sectors of the population. Wright and White's (1996:183) analysis of nutrition and pathology found no significant difference in health during the Classic period in the Southern Maya lowlands. However, they noticed a possible regional inconsistency in stress and suggested that local environments and political structures were too diverse to account for a generalized explanation for the collapse of Maya lowland populations.

For example, Gerry (1997) used carbon and nitrogen isotope analysis of human bone to suggest that the Belize River Valley was home to some of the highest dietary diversity within the Maya lowlands, demonstrating that food choices in the eastern lowlands differed from those at Maya centers Tikal and Copan. White (1997) compared stable isotopes to dental pathologies at Lamanai and Pacbitun and found that the Lamanai population was consuming equal amounts of plant and animal proteins throughout the Classic period. In contrast, the population at Pacbitun heavily increased its maize consumption just prior to the site's abandonment during the Terminal Classic (White 1997:180). Examination of microdefects at the Maya lowland sites of Tikal, Seibal, and Barton Ramie shows a significant increase and prevalence of stress at the end of the Classic period (Danforth 1997). While the evidence was deemed to be "weak" (Danforth 1997:137), there was a significantly greater rate of health disruption at larger centers during the Late Classic than among rural communities during the same time.

There is other evidence for stress during the Late and Terminal Classic periods. Battles are frequently depicted in the iconographic and archaeological record, and studies in western Guatemala in particular have documented warfare, immediately followed by the abandonment of Maya centers such as Aquateca (Demarest 2004; Inomata 2004). There is glyphic and archaeological evidence elsewhere for conflicts between major Mayan centers (Garber 2004;

Navarro Farr et al. 2008; Yaeger 2005), and though most are not directly linked to site abandonment, population movement was endemic during this period as evidence by the eventual large scale abandonment of most urban centers by AD 900.

Within the Maya lowlands, the majority of burial populations show similar demographic trends in the age ranges of individuals that are recovered from Classic Maya excavations. Storey suggests that at sites like Barton Ramie, Xunantunich, Chaa Creek, which are located within the BRV, the majority of the of the individuals recovered reached an adult age at the time of death. Excavations at Barton Ramie recovered 117 individuals. Age estimates for 70 of these individuals include subadults less than 20 years of age (8.7% <10 yrs, 31.8% 10-19 yrs) and 59% adults (20+ years of age) (Willey 1982). This is similar in the Xunantunich population (13% <10 yrs, 9% 10-19 yrs, and 79% adult) and the Chaa Creek burial population (7% <10 yrs, 0% 10-19 yrs and 93% adult).

At the site of Copan in Honduras, to the south of the Maya lowlands, the demographics of the burial population do not match those of their northern counterparts. Copan has higher percentage of younger individuals, with 64% subadults (30% <10 yrs and 34% 10-19 yrs) and only 36% adults (Miller Wolf 2015). Rebecca Story (1999) proposed that it was not the result of a cultural shift in burial practices, but an increase in stress or health-related issues that account for the large number of subadults. Chapter 4 discusses evidence of health and stress-related findings within skeletal material and how they may account for observable differences within burial populations.

Bioarchaeological examinations of Classic period skeletal material have focused on understanding population dynamics and how skeletal remains can help contextualize the archaeological record (Cucina 2004, 2011; Garber 1999; Glassman 1995; Harvey 2010; Lund

2003; Storey 1999; Wright1997). These studies focus on health related markers found in the skeletal assemblages. Transitions through different stages of life are marked by both biological and social changes (Prowse 2011:429). The wellbeing of a population can be correlated with the presence or absence of infection. It also reflects the ability of those who have stress markers to endure illness, malnutrition, and injury. Archaeologists can understand the life history of not only the individual, but the population as a whole using a biocultural approach (Glencross 2011:390).

The biocultural approach is the examination and incorporation of both biological and cultural influences observed within the archaeological record. This approach has increasingly gained recognition within the last 20 years as refinement of osteological methods combined with new understandings of cultural practices. Cultural traditions surrounding burials were complex; in order to use Maya burial populations to understand the variation in health and other questions about the living, we must understand the Maya burial practices and how they varied by region.

Archaeological excavations throughout Mesoamerica have recovered skeletal remains from hundreds of sites in monumental architecture, household structures, and caves and rock shelters. Archaeological interpretations of the burial assemblages have focused on health, status, royal histories, diet, and even migration (Chase and Chase 1996; Freiwald 2011; Freiwald et al. 2014; Gillespie 2002, 2011; McAnany 1998, 2011; Schwake 2008). However, we still have a limited understanding of the ritual practices that took place during the funerary cycle and their meaning. Most interpretations of burial practice stem from early concepts in social anthropological theory. I will briefly overview these early theoretical paradigms; specifically, functionalist views that emphasize social cohesion before turning to their influence in recent biocultural interpretations of mortuary practice in Classic (AD 200- 900) Maya communities.

Theoretical Frameworks for Mortuary Studies

The early twentieth century laid the foundation for cultural interpretation in anthropology and archaeology in particular. Culture-historical archaeology and new methods in prehistoric archaeology during the late nineteenth and early twentieth century were just the beginning. The social anthropological theory of functionalism, following the Durkheimian approach of the late 19th century, was adapted by Malinowski, Radcliff-Brown, and Mauss, and would pioneer the functionalist perception through 20th century archaeology.

The Durkheimian approach focuses on society as whole and how society creates social cohesion and solidarity. For Durkheim, larger societies have a greater level (and more “organic” type) of social complexity than much smaller societies, which rely on “mechanical” solidarity. Despite differences in population size, society generally conforms to natural laws while promoting the goal of social cohesion. Society is governed not strictly by the written laws of the government, but rather the unwritten laws that Durkheim terms as social facts. Social facts are the laws within a society that exist within the minds of individuals and drive their behavior. People obey these laws in order to maintain the social cohesion of the society. The idea of the 'collective conscience', coined by Durkheim, is the driving force that governs the unwritten laws amongst people in a society. People abide by social facts because not following them would be considered taboo, and the individual who breaks laws risks defeat and shame within the social collective.

Taking from this approach, both Malinowski and Radcliff-Brown believed that "human behavior could be understood best in relation to social systems that were conceived as made up of functionally interdependent elements" (Trigger 2009:319). Radcliff-Brown and Mauss take differing theoretical standpoints on maintaining social solidarity within civilizations from

Malinowski. Radcliff-Brown emphasizes that kinship systems as a whole work together to maintain social order (structural functionalism), whereas Malinowski places the importance on individual action (psychological functionalism).

Malinowski spent an extensive amount of time studying and collecting ethnographic data on the continuous exchange system of "Kula" in the Trobriand Islands, which is the exchange of adornments passing from island to island and individual to individual and illustrates his theoretical framework. Malinowski describes how the Kula operates and the rules of exchange. The Kula is an integral part of the culture and depends on the relationships between trade partners. Malinowski's 'psychological functionalist' view was that there are seven universal biological and psychological needs in maintaining solidarity (McGee and Warms 2012:155). These needs are that of solidarity and partnership, as the exchange is of cultural materials that have no practical value or usage. While there is little real value for the adornments that are exchanged, they hold a large culturally intrinsic value. Malinowski compares them to the Crown Jewels (McGee and Warms 2012:160). Relationships between trade partners are essential because “this partnership is a lifelong relationship, it implies various mutual duties and privileges, and constitutes a type of inter-tribal relationship on an enormous scale” (Malinowski 1922:85) that fulfills these basic needs.

While Malinowski emphasizes the individual's needs, Marcel Mauss would argue that one must look to society in its entirety to uncover total social facts. Keeping in line with Durkheim’s belief that societies work as a means of maintaining solidarity amongst their members, Mauss analyzes the practice of gift giving. According to Mauss, “a gift necessarily implies the notion of credit” (Mauss 1924:36), meaning that when a gift is given the one who receives the gift is obligated to return the favor. In his descriptions of potlatch, Mauss emphasizes that the act of giving a gift is equally as obligatory as the act of receiving. The obligation between gift givers demonstrates that there is no such concept of a free gift; instead, "gift cycles engage persons in permanent commitment that articulates the dominant institution" (Mauss 1924:ix). That is, there is an obligation to give and to receive or lose dignity (Mauss 1924:13). The idea of losing one's dignity as a result of not participating in the exchange of gifts is a powerful tool in the maintenance of the potlatch. This goes along with Durkheim's framework by demonstrating how the practice of gift-giving is a means of maintaining social cohesion and solidarity. People maintain the potlatch because to go against the practice means the person will lose face.

Gift giving among societies represents total social phenomena. It is evident that both the potlatches amongst North American tribes and the Kula ring amongst the Trobriand Islanders represent total social phenomena (Mauss 1924:3). Since both of these involve many aspects of a society and involve the processes of reciprocity, Mauss uses them as evidence to support his theory of total social phenomena. Mauss wants to understand the obligatory nature of gift giving in these societies because reciprocity is still prevalent in modern western society (Mauss 1924:3). By utilizing cross cultural analysis, specifically the potlatch and the Kula ring, Mauss uses one system of reciprocity in order to understand another system of reciprocity.

The influence of Durkheimian theory has played a major role in how bioarchaeology interprets the role of the individual within the contexts of a society. Specifically, the Durkheimian concept that society is a self-regulating system that influences an individuals' behavior sparked a shift toward "methodological individualism" (Gillespie 2001:73-74). Mauss' developed the concept of "personnage" to understand the relationship between kinship ties or clans and ancestor veneration (Gillespie 2001:82), which is essentially understanding the interrelationships that result in a sort of reincarnation where the person takes on the embodiment of those within their lineage. It is with this influence that the paradigms of agency, structuration, and practice develop and now play a strong role in the sub-discipline.

Theorists like Giddens and Bourdieu also theorized explanations for generalized maintenance of social order. For example, Bourdieu's Theory of Practice (date) explained how people's habits, ingrained in the existing social order, helped to maintain it. Practice theory seeks to explain the relationship between human action, on the one hand, and some global entities which we may call 'the system' on the other (Ortner 1984). Practice is what people do, and practices within a culture or a system are carried out by the actor, made up of rational thought and motivated by political and material reasons. The rationality that actors feel for their actions comes from the context of their own cultural history and is motivated by 'the system' (Ortner 1984). The system is essentially the cultural surrounding that controls the individual, restricting certain rituals from being performed by shaping the way in which we view these actions and the implications of said actions on the surrounding system.

In order to fully understand the implications of practice, we must account for the 'agency' behind practice. Agency is viewed as the capacity of the individual to act, and at any given moment, the individual has the capacity to do what he or she deems necessary (Hegmon 2003:219). Actions of an individual within a social collective are controlled by what Pierre Bourdieu called the "habitus" or individual interactions that shape the way in which we act in a given situation, either consciously or unconsciously. Agency has been described as the underlying thought process that drives practice as its "behind the scenes" structure (Hegmon 2003). While the system may control or change the agency of the practice, at the same time the individual is having an equal effect on the system. This habitus reinforces past conditions of their existence.

During the 1980s Anthony Giddens developed his structuration theory, and coined the concept of "Duality of Structure". In a sense practice, agency, and structure are not individual; one cannot exist without the other. Giddens "Duality of Structure" is the idea that individual agents drive social change/structure as aggrandizers. Through either conscious or unconscious activities agents reinforce social structure; "structure is both a medium and an outcome of production of practice" (Shennan 1996:286). Physical anthropology has adopted these concepts and applies them to how we view an individual within a society. Burial practices represent another type of total social phenomena when cultural "norms" are recreated through ritual surrounding death.

Interpretations of the individual within the context of a society allow us to reconstruct the individual's life history and the social facts- the driving forces of a culture-that shed a different perspective on not only the individual, but the culture in its entirety. Understanding the relationship between the living and the dead is an important tool for reconstructing different cultural identities. Identity can be viewed as a reflection of an individual’s status within the community he/she was born into and could also reflect the status of individuals who might have migrated into the group and the role in which they played as members of that community (Binford 1971; Chase and Chase 1996; Freiwald 2013; Freiwald et al. 2014; Gillespie 2002, 2011; McAnany 1998, 2011; Schwake 2008). Interments within a structure can indicate the individual’s relationship to the social house. In keeping people close they “creat[e] a social memory or identity for the domestic group” (Sullivan and Mainfort 2010:11). The creation of a social memory ensures that the deceased can have a safe passage to the other world or can properly be reincarnated. Social memory is not only for the living, but for the dead as well. The ways in which people are interred or handled after death reflect not only the dead, but are important and symbolic for maintaining order for the living as well.

Burial practices reflect the living even more so than the deceased, because the dead are spoken for through the living (Wood et al. 1992). This is evident in the burial practices that took place amongst the Maya throughout the Classic period. As in the works of Mauss, cross-cultural frameworks can be supplemented by ethnographic studies to explore, in detail, how social order is reproduced by the living and the dead. This is important for scholars of the ancient Maya, whose complex burial practices require modern analogies for interpretation of the past (Freiwald 2013; Freiwald et al. 2014; Gillespie 2002, 2011; McAnany 1998, 2011). The following section includes ethnographic accounts of modern and historic Maya groups that describe the burial process and its meaning that are useful for interpreting the physical remains of earlier Maya communities.

The act of burying the deceased in many regions is not seen as just the disposal of a body, and death in many communities throughout the world does not take place at the time of the last breath (Weiss-Krejci 2011). The practice or ritual of mourning and burial preparation that takes place exemplifies the transitional period from life to death and eventually the afterlife. There are multiple stages to a funerary process. I will discuss the meaning of life, death, burial and reintegration during the afterlife as seen by the Pich, Lacandon, and Zinacatecan Maya through ethnographic accounts. I will first introduce the concept of rites of passage and liminality as presented by Arnold van Gennup (1909) and Victor Turner (1987) as they are integral to the interpretations of the individual and social collective through the study of mortuary practice.

During the late 19th and early 20th century, Arnold van Gennup took to evaluating the cultural phenomena that take place throughout an individual's life; that is, cultural traditions that make up significant episodes of one’s life. These periods are one of transformation from one fixed state to another within a cultural construct. The birth of an individual, reaching adolescence, graduating from high school, marriage, child rearing, and even death are periods that van Gennup has termed rites of passage. During these events, van Gennup describes a three stage process that takes us from one form within the social collective to another. These stages are: "Separation" or the disconnection from a previous, fixed, stage in life that has been fulfilled; "Margin" the period in which the actor is in a place of liminality or ambiguity between two culturally recognized classifications; and the final phase of "Aggregation", which is the reincorporation of an actor within the social collective. Here the individual once again has "rights and obligations of a clearly defined and "structural" type, and is expected to behave in accordance with customary norms and ethical standards" (Turner 1987:5).

Taking from the rights of passage presented by van Gennep (1909), Victor Turner (1987) focuses on the phase of liminality as it is farther detached from social structure than separation and aggregation, which can be viewed as fixed positions within the social collective (Turner 1987). The transitional phase(s) of rites of passage is controlled by our cultural definitions and classifications. During separation one would be classified as a boy; then, during aggregation, classified as a man.

The "liminal persona" is much more ambiguous. For example, "a society's secular definitions do not allow for the existence of not-boy - not-man" (Turner 1987:6). That is, during the liminal stage, an individual holds two characters within the cultural construct; the no longer classified and the not yet classified. For the purpose of this essay I focus Turner’s examples of death and burial. For those undergoing separation or no longer classified, we ascribe terms that hold a negative connotation, such as death and decomposition. Those in the later stage of passage are met with terms like embryo and newborn (Turner 1987:7). Throughout the entirety of the passage, more so during the liminal stage, symbolically an individual is "neither living nor dead from one aspect and both living and dead from another" (Turner 1987:7). The funerary cycle itself, with its extended period of liminality, is an important contributor to understanding and contextualization of cultural constructs. It is during the liminal phase that all are void of any hierarchical ranking and classification. For a moment, this is a time of complete solidarity amongst individuals within a social collective. The liminal phase is the most influential time culturally as it "exposes the basic building blocks of culture" (Turner 1987:18) and is the moment where the boundaries of agents and communities collide.

Ethnographic Studies of Maya Funerary Practices and Beliefs

Death, the Maya believe, is the loss of the soul; "no death results from what we consider natural physiological causes" (Vogt 1969:217). The practice or ritual that takes place exemplifies a transitional period from life to death, a transition that marks the beginning of the social death of an individual. The completion of the social death of an individual, especially in Classic Maya communities, took place during the "re-integration" phase of the funerary cycle (Weiss-Krejci 2011). At this time it was believed that the deceased individual was not becoming disconnected from social life, but was being re-incorporated. The placement of the body was an offering made so the soul could begin the next phase of life by becoming one with earth and eventually being reborn as something else (Weiss-Krejci 2011:71).

Faust (1998) examined and detailed the meaning of death and the rite of passage through ethnographic and iconographic study of a Maya community in Pich, Mexico. While studying everyday interactions, Faust (1998) gained insight into the cultural interpretation of the life cycle as represented by the Maya cosmological beliefs. The life cycle as they explained it was analogous to seasonal change and the daily cycle of the sun and moon. That is, birth, in the perspective of the Pich Maya informants, was analogous to the sunrise, death was viewed as the sunset, and burial was the representation of decay with the eventual new sunrise (new life) representing the afterlife.

When referring to the life cycle, the Pich Maya believed that both plants and humans follow the same trajectories as the rising and setting sun, as well as the changing of the seasons (Faust 1998). The initial sprouting of a plant begins the with spring equinox. It grows throughout the summer until the coming of the fall equinox, when death occurs and decay begins. Winter months are the time of disintegration and reintegration of the plant matter into the earth, where it awaits the following spring for rebirth and continues another cycle as new plant life is reborn from the previous deadfall. This life cycle of agriculture is also translated to humans, but is more directly analogous to the daily cycle of the sun and the moon (Faust 1998). The rising of the sun is analogous to the birth or beginning of a new life, which will continue to grow throughout the day until the sun begins to set. The setting of the sun begins the transitional life phase into death, which is completed as the moon rises and 'midnight' strikes, and the process of decay and re-integration (burial) begins. As the sun rises, rebirth in the afterlife is complete and the soul of the recently deceased will live on in the coming of a newborn child.

While the transitional phases and rites of passage throughout life are many within Maya communities, and many cultures for that matter, the latter portion (decay and reintegration phases) of life is the focus of many bioarchaeological studies. While many Maya groups believe in a cosmological life cycle, there is another cycle that takes place starting at the time of death. The funerary cycle prepares the individual and the survivors of the individual for the afterlife, which begins with the preparation and care of the deceased.

The entire funeral process among the Lacandon Maya was meant to help the dead begin the journey to the underworld, where the deceased would encounter, amongst other things, chickens, lice, dogs, and a river full of alligators (Freiwald et al. 2015; McGee 1990). This journey is a liminal state where the deceased either pass judgment and continue on to live in the heavens, or are condemned and restricted to living an eternal life amongst the flames. This liminal stage varied in length depending on how long the person lived.

Death was the beginning of the soul's journey. Practices such as honoring the dead by providing burial goods/offerings or application of oils and adornments took place during the time of mourning and provided the means for the deceased to pass the obstacles on the road to the underworld. For example, corn was placed with the dead to distract the fowl, and a handful of hair would keep the lice from frightening the soul (Freiwald et al. 2015; McGee 1990). The deceased would be carried over a river by a black which was paid with tortillas, and then on to a fork in the road where judgment occurred. This dog, for the Lacandon, was the representation of his/her own dog, and the owners lifelong conduct directed towards the animal companion determined the loyalty of the dog needed for safe navigation of the waters (McGee 1990). Once across the river, the deceased reached the place of final judgment. The funerary activities were the last influence the living could have on the dead for safe passage during the final stage of the journey.

Burials described in the ethnographic accounts had an east-west orientation and supine position. The body was placed with the head to the west so that the individual would face east (McGee 1990:116). Lacandon accounts say that facing the east symbolizes the soul’s life after death as the person is looking towards "Yaxchilan" (the home of the gods) and the rising sun (symbol of rebirth) (Faust1998; McGee 1990:116; Redfield and Villa Rojas 1934). While the ethnographic accounts of the Zinacantan Maya do not directly explain the reasoning for this orientation, when facing the east the gods would be on the right shoulder and the demons on the left. The eastern facing orientation during the funerary process may assist in guiding the Zinacatecans once they reach the place of final judgment.

Modern and historic ethnographies show that the funerary process continued for days as the soul made its journey through the underworld (McGee 1990; Vogt 1969). Food and offerings and visits to the grave may continue for years; the Classic period Maya described periodic commemorations of deceased ancestors (Freiwald et al. 2015; McGee 1990; Vogt 1969). The studies also suggest ways that different Maya groups may have merged Christianity with indigenous beliefs over the centuries (Freiwald personal communication).

An individual's conduct during life would be the deciding factor not only his/ or her journey but final resting place as well (Faust 1998; Freiwald et al. 2015; Gillespie 2001, 2002, 2011; McAnany 1998, 2010; McGee 1990; Redfield and Villa Rojas1934; Vogt1969). At the final place of judgment, the soul was met by the "lord of the underworld" and a fork in the road. If the soul was accepted by the lord, it was led down the path on the right to live with relatives in the heavens. If denied, the soul will be given to Kisin (the god of death) and led down the left path to the fires of Metlaan. Here the soul would answer for ill thoughts and conduct towards his/her family and friends. Kisin burned the soul with a red hot iron for each act and then threw it into the fires.Once the soul was completely consumed by the fire, Kisin reached in and altered the soul into the form of an animal so no human could be reborn from a turbulent soul (McGee 1990:111). Children were led straight to heaven if baptized prior to death, and those who died unbaptism were thrown straight in the fires and given to the demons as they had "no fixed souls" (Vogt 1969:222). Upon completion of its journey, ones soul could be reincarnated. The information we have from ethnographies shows that locations, burials goods, and other aspects of mortuary treatment all had meaning, and that with each funeral, people were reproducing the symbolic actions that guided community members from death to the afterlife, but that also linked ancestors with future generations. Detailing the closing of a social death through ethnographic accounts allows for a more holistic interpretation of material remains recovered from an interment. The placement of the body was an offering meant to help the soul begin the next phase of life by becoming one with earth and eventually being reborn as something else (Weiss-Krejci 2011:71).

The completion of the social death of an individual, especially in Classic Maya communities, takes place during the "re-integration" phase of the funerary cycle (Weiss-Krejci:2011). At this time, the deceased individual is not being disconnected from the social collective, but rather is re-incorporated within the social structure. From the study of this liminal phase we can gather what is being used for a means of social death and what ways this practice also symbolizes social memory within the Maya communities.

Social Memory and Re-Integration

The addition of ethnohistoric and ethnographic research to the study of mortuary rituals allows for a more holistic interpretation of the material record that is recovered by archaeologists. Direct accounts from living populations give us the advantage of getting the emic views that are not always present when looking at material culture and illustrate to us how and why selected culture practices are performed today. Although cultural practices change with every generation to some extent, Mayanists employ a direct historical approach to interpret and/or hypothesize funerary practices in the past. It is through the previously discussed ethnographic accounts and theoretical paradigms that the following interpretations of the place and space of Classic Maya burials have arisen.

Study of funerary practices may illustrate the circumstances of a person's life (Gillespie 2002, 2011; McAnany 1998, 2011). As typical "good life" burials incorporate some offering for a prosperous afterlife, those who with a "bad death" due to circumstances of their life history are not given the same recognition or proper ritualized burials (Weiss-Krejci 2011). Examples of a typical "bad death" could include burials without much attention or lack of preparation and/or associated burial goods. Further, these burials have been attributed to persons participating in witchcraft and sacrifice or death due to communicable disease, all of which are judgments placed upon the dead by the surviving community (Wiess-Krejci 2011). However, Freiwald (2012) suggests that place was at times more important than the individual, which may provide an explanation of a lack of burial investment for individuals at some sites. It is equally important to note how many burial offerings were perishable and would leave little to no material record at all.

Gillespie (2002, 2011) explored social memory amongst the deceased in Maya culture. For example, in the Maya community names are not given to an individual, which is typical in western culture, but belong to the family (Gillespie 2001, 2002). The name is not given to the child, but the child given to the name as the name lives on in reference to the lineal descendant.

Continuation of lineal descent through re-birth is a claim to social memory. Gillespie (2002) references the afterlife and rebirth of an individual. The newborn child is born with the soul of a previously living individual and is given to the name of the person whose soul has been instilled in their body. This is seen or described as a newborn baby that has a full head of hair, bright (open/wandering) eyes, or is born with teeth.

As individuals die, they are not relieved of their family roles. It is said that a person's soul will live on through their name and continue to express itself through the new body. These social memories and ties to lineal descent do not stop at body, soul, and name of individuals. Final placement of an individual, during the re-integration phase of the funerary cycle, has a primary role in social memory.

McAnany (1998, 2011) suggests that ancestors created links to land claims, and may have played a role in the rank a lineage held as it competed with other groups, including the ruling family. Typical burial locations within the Maya region are centered on structures. Whether that structure was a household, ceremonial, monumental, or a marketplace structure, the burial of an ancestor may have been necessary to renew a family's ties to a specific location. In keeping people close the Maya could "creat[e] a social memory or identity for the domestic group" (Sullivan and Mainfort 2010:11). The Classic Maya may have perceived that landownership never left that of the original owner. Though the incorporation of the previous head of household within the foundation of the structure the living, descendants were holding the land for the head of household until one was reborn and reclaims as rightful heir (Gillespie 2001, 2011; McAnany 1998).

Gillespie (2011) explored the deposition of individuals in different areas throughout Maya sites. While looking at burial placement, she found significant variation in burial placement within a household structure or outside the household. Within many Maya communities, interment within the structural foundations holds the highest meaning as one will is a part of daily memory within the living structure. People buried within a structure can indicate their relationship to the social house. As done with the soul and a name, the remains of an individual are ritually used to continue ties of property ownership and lineal descent. Maya typically buried loved ones within the household or family owned structure as a way to keep memory alive. When placed outside of the structure, the connotation is that this individual is not worthy of such social memory and may be a forgotten descendant removed from lineal descent based on life history (Gillespie 2011). Detailing and incorporating variations within a burial context can demonstrate the broader significance of mortuary practices.

Bioarchaeologists often focus on the remains of the body itself. While the east-west orientation and supine body position is consistent with Christian beliefs, variability in body placement among Classic Maya centers has strong regional patterns (Freiwald 2011). However, it is only recently that archaeologists have begun to apply studies of modern and historic funerary processes to past Maya burial practices.

Burial practices vary spatially and temporally, and may provide the best evidence for close relationships among families and communities in different polities. Funerary rites are considered resistant to change within most cultures. They are rituals and “thus, rituals including mortuary rites, have an element of unchanging timelessness about them. They invoke from the distant past (“so it has always been”) to the future (“so it always shall be”)” (Mainfort Jr. and Fisher-Carroll 2010:128). However, even the most hallowed rituals change over time, sometimes ever so slightly as to be perceived as timeless. The timelessness of burial practices is only a perception, and similar to other aspects of culture, they do undergo change. These practices are generally, however, the last to change within a society.

In a sense, burial practices are a total social phenomena where the community or social house participates through a culturally prescribe fashion to commemorate the dead. This is evident in third wave bioarchaeological theorywhere one can see the impact of Durkheim, Mauss, and Malinowski and postmodernism that recognizes the importance of contextual information outside of the interment. “In building a social bioarchaeology, scientists are engaged in the construction of the biological and social essence of individuals from the ground, or if you will skeleton up” (Agarwal and Glencross 2011:3). Essentially in performing a social bioarchaeology, the bioarchaeologists are attempting to uncover the total social facts of a society by incorporating not only biological material but also ethnographic and archaeological materials.

The incorporation of ethnographic accounts into our interpretations of Maya burial practice shows that all parts of interring the dead had meaning. With each funeral, people were not only reproducing the symbolic actions that guided community members from death to the afterlife, but that also linked ancestors with future generations. Regional differences, and variability within Classic Maya burials, result from agency and both intentional and unintentional efforts of actors working within a cultural system. Most often these variations are due to agency within the individual's social structure and may reflect family and community members more than the individual. However, variation in burial populations may not be solely attributed to the identity of those who interred the dead, but to the life history of a given population.

This study considers cultural factors as well as biological ones, comparing sites with similar burial locations, typologies, positions, and orientations. The burial populations from the inland site of Actuncan and the coastal sites of San Juan and Chac Balam from the Ambergris Caye share many similarities in spatial and temporal deposition of the burials. However, there are significant differences in demographic profiles of the burial populations, and health differences offer one possible explanation.

Ambergris Caye

Ambergris is referred to as an island, but is in fact a peninsular land formation located in the southern Yucatan, which is also a peninsula. Excavations of the Ambergris Caye began in 1985 under the direction of Thomas Guderjan (Guderjan 1995). The initial scope of the project was to focus on San Juan to understand what, if any, influence the Ambergris Caye populations held in Maya maritime trade (Guderjan 1995). The expansion of the project came soon after initial excavations were completed and the research potential of the Ambergris Caye sites was realized (Guderjan 1995). Expansion of archaeological investigation into Ambergris Caye established that multiple sites played a role in Maya maritime trade during the Late and Terminal Classic and into Postclassic periods. Ambergris Caye is home to twenty-two residential sites and two that are non-residential. Most structural, material, and skeletal information came primarily from the two northernmost sites of San Juan and Chac Balam.

Ambergris Caye was centrally located within the trade route along the coast, which made it the ideal location to house a large trade hub between the north and the south. The variation between structures at the sites of San Juan and Chac Balam shows interaction or trade with both northern and southern communities in the Maya lowlands (Guderjan 1995). San Juan's architecture is similar to that of the major Maya center Tikal, which is located in Guatemala, and Chac Balam's architecture is similar to plazuela groups at Chichen Itza in the northern Yucatan.

While San Juan and Chac Balam are mainly residential in nature, during the excavation it was apparent that all structures, even the elite household structures, were not limited to residential activities. The abundance of trade materials found within the structures led to the conclusion that the entire community was involved heavily in the maritime trade, which along with proximity to coastal resources, provided a rich environment. Easy access to protein-rich marine food sources and exchange of high quality terrestrial protein sources would allow Ambergris Caye populations to sustain less stress prior to weaning as protein is a vital nutrient during development.

Ambergris Caye Burial Population

Excavation of San Juan and Chac Balam residential complexes resulted in the recovery of 42 individuals found in 36 burials, including single and multiple interments. All individuals were recovered from residential patio groups that held single family structures and multi-use structures which served primarily as single family residences (Garber and Guderjan 1995). Due to the condition of many burials, only fifty percent of the population's burial position and orientation were determined. Standard burial treatment included placing the body in a semi-flexed, supine, or fetal (side) body position, with the head oriented to the south. All individuals recovered from the Ambergris Caye were dated in association with construction phases and ceramic types to the Late and Terminal Classic periods. Determination of sex for the majority of individuals was inconclusive due to the fragmentary and the incomplete developmental state of most remains recovered (Glassman 1995). Of the 42 individuals recovered from San Juan and Chac Balam, 39 have been classified in discrete age groups (Table 1). The skeletal population from Ambergris Caye ranged in age from approximately 2 years to 35+ years of age. Of the 39 individuals, 56%

have been classified as subadult (35.9% <10 yrs and 20.5% 10-19 yrs) while 43.6% have been determined to be older than twenty years of age at the time of death.

Table 1: Ambergis Caye burial population

Ambergris Caye Population					
Age	0-9	10-19	20+	Indeterminate	Total
Disposal					
Primary	9	2	15	1	27
Secondary	0	0	0	0	0
Indeterminaet	5	2	5	2	14
Multiple	3	2	4	0	9
Individual	11	2	16	3	32
Postion					
Flexed		1	1		2
Semi-Flexed	6	2	2	1	11
Extended	1	0	6	0	7
Indeterminaet	7	2	7	2	16
Gender					
Male	0	0	9	0	9
Female	0	1	8	0	9
Indeterminate	14	3	3	3	23

Actuncan

Actuncan is located within the Belize River Valley on the eastern periphery of the Petén region (LeCount and Blitz 2002). This location allowed for Actuncan to be in continual contact with larger Classic period centers such as Naranjo and Tikal in Guatemala. Early excavations at Actuncan were directed by James McGovern in the early 1990s, who separated the site into two sections: Actuncan North and Actuncan South (LeCount and Blitz 2002). Actuncan South consists of three pyramids aligned in a triad configuration (LeCount and Blitz 2002:12). The primary construction phase at Actuncan South took place during the Middle Preclassic (1000 BC- 400 BC) with continuous occupation through the Classic period. The façade of the terraced structures in the southern section of Actuncan were adorned with large polychrome stucco masks much like those present at Tikal, and the construction phase dated to the Early Classic with the placement of a large stone stela situated in front of the largest structure.

The Northern division of Actuncan is considered to be a small civic center consisting of residential and non-residential structures, including a small ball court. Based on ceramic data, the initial construction of Actuncan North took place during the Early Classic and occupation of these structures continued along with Actuncan South into the Terminal Classic period, with limited Postclassic occupation similar ot that identified elsewhere in the Belize River Valley. The Actuncan population may have been subject to similar stresses during the Terminal Classic period as the central lowland centers with which they interacted. This is, stress can be explored further with the Actuncan burial population as the majority of interments are from the Late and Terminal classic period and no Postclassic burials have been recovered.

Actuncan Burial Population

Excavation of Actuncan's structures has recovered twenty-five individuals placed in sixteen burials. Most were in residential structures, which vary from single residential mounds to patio groups that include both multiple and single individual interments (Freiwald 2012; Freiwald et al. 2014). Standard burial treatment included placing the body in an extended, prone body position, with the head oriented to the south. Burials of the subadults predate the Classic period; however, most burials of adults date to the Late and Terminal Classic period. Sex estimation is limited due to the highly fragmentary state of many of the remains. Of the 25 individuals recovered, age determinations are made for 18 of them and range from 1-3 years to 30+ years based on skeletal analysis by Scopa Kelso (2005), Freiwald (2012) and Freiwald et al. (2014). Six individuals, or 33.4%, have been classified as subadult or less than 20 years of age (16.7% <10 yrs and 16.7% 10-19 yrs) and 12 individuals, 66.7%, are classified as adults (Table 2).

Table 2: Actuncan burial population

Actuncan Burial Population					
Age	0-9	10-19	20+	Indeterminate	Total
Disposal					
Primary	1	3	11	7	22
Secondary	0	0	0	0	0
Indeterminate	1	0	0	0	1
Multiple	0	2	5	6	13
Individual	2	1	6	1	10
Postion					
Flexed	0	1	0	0	1
Semi-Flexed	0	0	1	0	1
Extended	2	2	9	7	20
Indeterminate	0	0	1	0	1
Gender					
Male	0	0	3	0	3
Female	0	0	1	0	1
Indeterminate	2	3	7	7	19

Summary

Significant changes were underway in the Maya lowlands at the end of the Classic period. The population was growing, and social interactions among regions were shifting. Actuncan and the Ambergris Caye sites and likely faced similar pressures as trade routes and interactions with larger centers changed. Regional standardization in burial practices, especially in Belize, was a product of Late and Terminal Classic periods (Willey et al. 1965). The Ambergris Caye and Actuncan populations followed similar mortuary practices: a southern orientation which contrasts with the eastern, northern, or western orientations in other parts of the Maya lowlands (Welsh 1988); interment of individuals in residential locations; excavation strategies that emphasized on residential architecture. However, the burial populations are not similar. Actuncan's burial population mirrors many of those found within the Belize River Valley, with the low number of subadults as compared to adults. Burial demographics from the Ambergris Caye populations differ in that most individuals were classified as subadults. To address this difference in burial profile, I compare the health of these populations.

III: DENTAL ANTHROPOLOGY: HEALTH AND PATHOLOGY

While archaeologists are interested in reconstructing mortuary ritual in order to further understand Maya beliefs surrounding death, the information obtained from interments is not limited to physical structure and material culture in burial practice. The skeletal remains themselves can tell us a great deal about a person's life history. The study of paleopathology examines the evolution and progress of disease over time and how people adapt to changes in their environment (Roberts and Manchester 2010:1). With the abundance of skeletal material recovered from the Maya lowlands region, a large number of studies have addressed questions pertaining to health at major Classic Maya centers such as Tikal, Copan, and Caracol (Chase and Chase 1996; Hammond 1974; Haviland 1967). Recently, work has focused on recording pathological occurrences from smaller sites that were home to commoners and rural households in order to provide a more holistic understanding of heath variability and its relationship to status, sex, and age-related difference in the Maya lowlands (Adams 1998; Alfonso-Durruty 2011; Bogin 2012; Garber and Glassman 1999; Lund 2003; Lungmus 2007).

A brief overview of pathologies that are commonly found in archaeological populations precedes an in-depth discussion of dental defects, the focus of health-related problems in this study. The chapter concludes with studies on dental health and pathology and the broader implications they have for the health and well-being of Classic Maya children and adults.

General Pathology and Health

Pathological conditions that leave visible marks on bone are generally associated with disruption of normal growth processes, specifically during times of nutritional or metabolic stress. During times of heightened stress, the body's natural response is to keep the vital organs in working condition in order to combat disease and continue life while shutting down other systems. Supplemental energy must be appropriated from elsewhere when extra energy is required to maintain vital organs and combat infection and exhaustion. This may restrict new bone growth as bone (re)generation is more or less unnecessary energy expenditure during times of hardship (Alfonso-Durruty 2011; Roberts and Manchester 2010; White and Folkens 2005; White 2001).

Hardship on the overall bodily function can be caused by a number of conditions, including, but not limited to: genetic or congenital disorders, infections and disease, workload, and nutritional and/or metabolic stress. Stress indicators or pathological lesions that can be attributed to more than one condition are referred to as non-specific stressors. There are a number of non-specific stressors that can be attributed to degradation of a population’s health and nutrition.

Degenerative diseases, such as degenerative joint disease (DJD), osteoarthritis, and periostitis are the most common insults observed in skeletal assemblages. Observation and analysis of degenerative stress within past populations provides information used to reconstruct lifestyle and subsistence activity patterns. Degenerative diseases demonstrate age-related changes to the skeletal structure due to repetitive motion and continual exposure to mechanical stress in daily activities.

Osteoarthritis and DJD display the body's response to over load/ use stresses with the production of bony growths known as osteophytes. These boney formations occur in order to more evenly distribute weight and/or stress along the joint surface. The occurrence of joint disease in skeletal assemblages is atypical for the Maya lowland populations as a whole (Chase and Chase 1994, 1996; D. Chase 1994), but degenerative insults have been observed among coastal populations. Glassman (1995) and Lund (2003) observed several accounts of osteoarthritic lipping and osteophytic build up in the shoulder and elbow joints, which they believe were responses to the repetitive behavior associated with maritime activities like canoeing.

Periostitis is commonly assessed as a degenerative condition attributed to chronic stress to the periosteum, or the outer surface of the bone. Periostitis is also associated in many cases with infection, typically secondary to trauma and/or a congenital disease such as syphilis. Infections associated with small wounds or large lacerations cause inflammation that stretches or separates the periosteum from the cortical bone structure. Repetitive stress on the ligament attachments of long bones and swelling of the periosteum due to infection is typically indicated by striations that form along cortical bone structure during bone remodeling (Roberts and Manchester 2010). The striated remodeling is characteristically seen on long bones, primarily the tibia or fibula, and is typically referred to as shin splints in modern runners.

While degenerative diseases are classically recognized as the result of occupational or workload stress, other pathological conditions are attributed to nutritional stress as development and remodeling are disrupted during periods of malnutrition and environmental stress. Other stressors such as porotic hyperostosis, cribra orbitalia, and Harris line formation have been more directly linked to metabolic and nutritional stress.

Porotic hyperostosis is a generalized term used to address lesions that occur on the cranial vault and the orbital bones as the direct result of anemia. This is typically used to describe the presence of the lesion on the outer surface of the frontal, occipital, and parietal bones of the cranial vault. Cribra orbitalia is used when porotic lesions occur on the orbital bones or eye sockets. Both pathologies, whether located on the cranial vault or the orbits, manifest iron deficiency. Iron deficiency causes an increase in the production of red blood cells throughout the body, and the resultant pressure causes the deterioration of the outer table of the cranium. The rapid production of cancellous bone in response to the rapid absorption breaks down this outer table, leaving the porotic bone visible on the exterior surface.

Typically these porotic anomalies happen at a very young age, from 6 months to 2 years of age. The presence of porotic hyperostosis is a useful indicator of early childhood stress as it demonstrates deficiency during the rapid development of juvenile bone, a time when higher quantities of iron are needed (Robert and Manchester 2010; Wright and Chew 1998). Porotic hyperostosis is more prevalent in prehistoric societies as sufficient supplies of diverse foodstuffs may not readily accessible during the weaning period and transition to solid foods, especially in the Late and Terminal Classic periods (Wright 1997; Wright and Chew 1998).

Blom et al. (2005) looked at the frequency and severity of pathological manifestations of anemia among coastal populations in pre-Columbian Peru. Pathological observations were compared to age at death in order to estimate childhood mortality in relation to the severity and presence of cribra orbitalia/porotic hyperostosis. When scoring the severity of these conditions, the presence of cribra orbitalia was found to be non-severe, but when porotic hyperostosis was also present, the severity of both conditions were found to be significantly higher. Overall, their case study found an inverse relationship between age at death and anemia among the coastal

Peruvian populations; that is, a significant greater presence of anemia in the children than the adults. They also found that incidents of childhood anemia were greater in northern coastal populations than in southern ones (Blom et al. 2005).

Pathological conditions like the ones outlined above have been used to understand health and mortality at the population level; however, pathological occurrences on long bones show only stress occurring during the final stages of life. Skeletal structures are continually remodeling, so pathological expressions of previous injuries or illnesses, especially those during childhood, are often hidden because the bone already has remodeled. In contrast, tooth enamel remains relatively unchanged after it forms throughout an individual’s life (Cucina, 2002; Garcin et al. 2010; Goodman and Rose 1990; Goodman and Armelagros 1985; Hillson 1996, 2014; King et al. 2002; Colli et al. 2009; Wright and White 1996).

Morphological variations that take shape in human dentition are typically expressions of genetic processes or health and stress. The variations that are observed only take place during development of dental enamel; that is, tooth enamel is unchanged from its original formation, with the exception of dental wear, or in cultures such as the Maya, dental modification. Absence of reconstruction, along with the rigidity of the enamel structure, makes teeth the most readily available and most reliable structure for studying health and pathology, especially when exploring early childhood stress.

Dental Development

Human teeth consist of approximately 96% inorganic material, making them less susceptible to diagenesis after formation much longer than other anatomical structures. Unlike bone or soft tissues, tooth enamel does not remodel, encapsulating health information during its developmental period and giving anthropologists a tool for understanding a person's early life history and population health (Goodman and Rose 1990; Hammerl 2013; Prowse 2011). Severe stress may cause growth stoppages in tooth enamel, and the timing and severity of pathological occurrence is the main method used in this analysis. Therefore, a brief introduction to dental development is needed in order to understand how early life stress affects dental morphology.

Dental development begins *in utero* for all deciduous dentition as the fetus is developing. During this phase, tooth formation is carried out by dentin forming cells and enamel cells called ameloblasts in a process called amelogenesis. Beginning at what will eventually be the tooth crown, or the occlusal surface of the tooth, odontoblasts form the initial stages of dentin production and ameloblasts begin to produce a protein matrix consisting of hydroxyapatite, which crystallizes to form the enamel (Goodman and Rose 1990; Hillson 1996; Wright 1997). Ameloblastic production will continue to secrete enamel from the cusp cervically, juxtaposed to dentin producing cells, where the crown ends and the root structure begins, which also is known as the cemento-enamel junction (CEJ) (Figure 4).

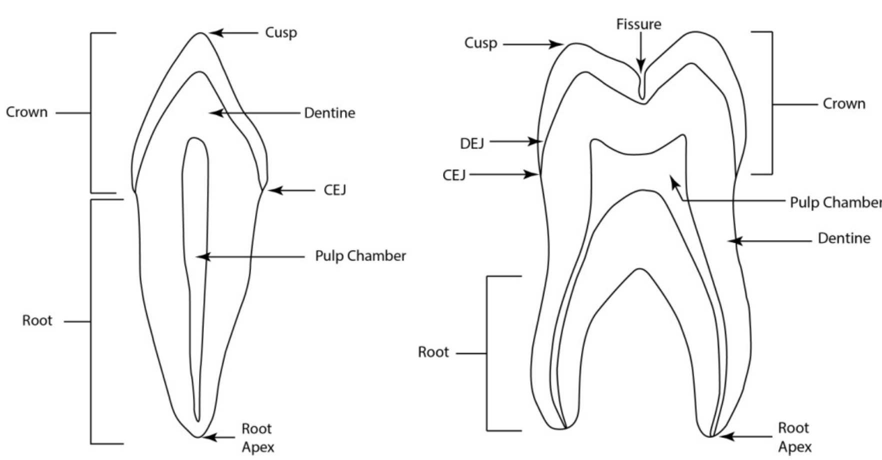

Figure 4: Tooth anatomy cross section: incisor (left) and molars (right) (Adapted from Ash 1984)

During the developmental process (enamel secretion) any significant stress, dietary, environmental, etc., disrupts enamel formation and leaves distinct malformations along the exterior surface of the enamel. The deciduous or "primary" dentition erupts from the crypt at approximately 6 - 24 months following birth. The lower central incisors are the first teeth to emerge at 6 months. Incisor eruption is sequentially followed by the rest of the primary dentition, from the anterior most teeth (incisors) distally to the molars. Prior to the eruption of the primary dentition, development or amelogenesis of the permanent dentition is already taking place. That is, the permanent teeth are forming well before the primary teeth have even breached the gum line. Crown formation of the permanent dentition occurs as the deciduous roots are resorbed. The crown of the successor tooth will essentially take the place of the primary root within the crypt.

Enamel formation of permanent dentition begins with the production of the mandibular first molar where amelogenesis starts at or around time of birth, followed by the central incisors and continuing distally throughout early childhood. At approximately seven years of age, permanent teeth begin to erupt and replace the deciduous dentition. Amelogenesis begins at the occlusal surface, or tip of the tooth crown, and builds towards the root, discontinuing enamel formation at the CEJ. Following completion of the enamel matrix secretion, root formation and eruption of the permanent dentition begins. At age 6, the maxillary and mandibular first molars, as well as the anterior teeth (incisors, canines), have completed crown formation and have begun to replace the deciduous dentition. LEH and other indications of stress on deciduous dentition and early-forming primary teeth reflect an individual’s life history during infancy.

Enamel Hypoplasia

Early childhood stress may result in abnormalities in the production of tooth enamel that are known as hypoplastic defects. Hypoplastic defects are representative of severe traumatic events, such as injury, infection and illness, malnutrition, weaning, and/or dietary restriction. Any of these events, if significant, may restrict or disrupt enamel development and leave one of three types of enamel hypoplasias: lines, pits, and/or grooves. The most common defect that presents evidence for stress, especially related to diet, is the line, which is referred to as linear enamel hypoplasia (LEH) (Figure 5) (Goodman 1996; Hillson 2002; Larsen 2003; White 2005; Wright and White 1996). Analysis of linear enamel hypoplasias has been used to establish the age of childhood weaning and stress patterns of many populations (Colli et al. 2009; Cucina 2011; Goodman 1996; Goodman and Rose 1990; Hillson 2002; Storey 1997, 1999; White 2005; Wright and White 1996). Nutritional deficiencies and stress during infancy and childhood may disrupt the development of the tooth, leaving visible effects in the enamel, or areas where enamel is thinner than on the rest of the tooth (Goodman 1996; Goodman and Rose 1990; Hillson 2002; Larsen 2003; Storey 1997, 1999; White 2005; Wright and White 1996).

More specifically, dental enamel hypoplasias are caused by severe disruption of growth at one or several of the Brown Striae of Retzius, which are incremental lines associated with ameloblastic production that run from the convergence of the dentin and enamel lines (the dentino-enamel junction or DEJ) to the enamel surface where they terminate in small grooves called perikymata (Hillson 1996, 2014; Wright 1990). Brown Striae and Wilson bands have been determined as expressions of stress episodes or changes in enamel prism structure lasting between 8 and to 10 days (Goodman and Rose 1990; Goodman and Armelagros 1985; Hillson 1996, 2014). These identifying features of changing enamel structure are typically identified microscopically. Enamel hypoplasias, on the other hand, can be identified macroscopically as intensified disruption stunts ameloblastic production, not allowing for congruent lengths of enamel secretion (from the DEJ to enamel surface) between one or more perikymata. This disruption in enamel secretion leaves behind large furrows along the enamel surface (Cucina, 2002; Goodman and Armelagros 1985; Goodman and Rose 1990;; Hillson 1996, 2014; King et al., 2002; White 2005; Wright and White 1996).

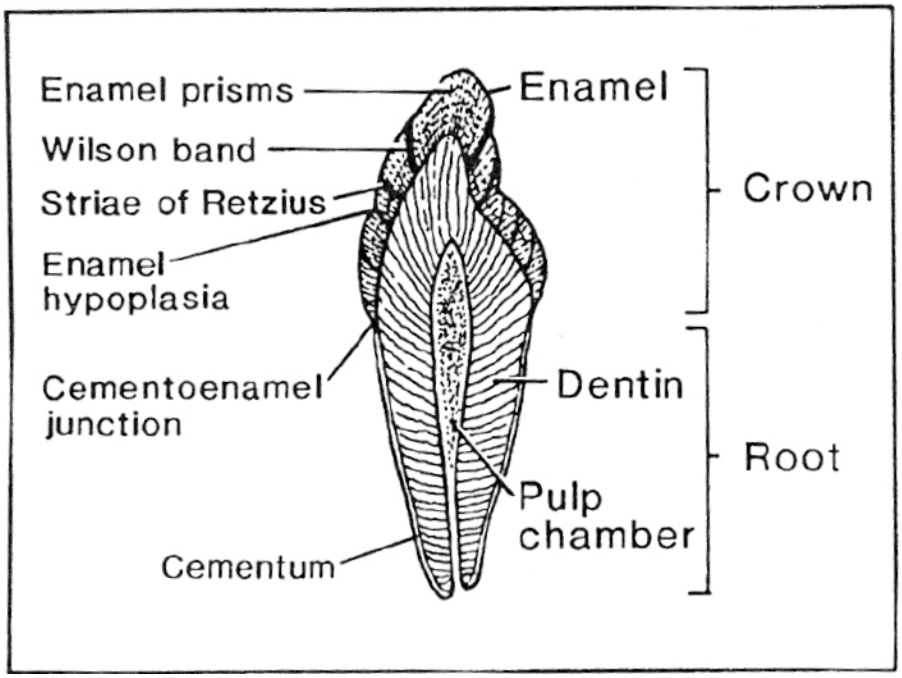

Figure 5: Cross section of lateral incisor showing microdefects found in enamel (Adapted from Goodman and Rose 1990:62)

Goodman and Rose (1990) designed a metric analysis to determine when the disruption occurred based on the location of the LEH on the enamel. Since its inception, this method has been used across the globe with great success to study both contemporary and ancient populations (Hillson 1997; Ritzman 2008; Wheeler 2009; Wright 1997). Sliding calipers are used to measure the distance from CEJ to the incidence of disruption on complete crowns.

Comparing the locations of the defect(s) to tooth crown formation schedules can be used to identify the approximate age that the defect occurred and provide a chronology of stress episodes for an individual (Cucina, 2002; Goodman and Rose 1980, 1990; Hillson 1996, 2014; King et al. 2002).

It has been argued that juvenile morbidity rates are the best indicator for assessing generalized health patterns for a given population (Cucina 2011; Goodman and Armelagros 1985; Halcrow and Tayles 2011; Hillson 1997; Huss-Ashmore et al 1982; Larsen 1995, 1997; Prowse 2011; Sofar 2011; Storey and McAnany 2006; Wheeler 2009; Wright 1997; Zuckerman and Armelagros 2011). A significant proportion of non-specific stress occurs during the early stages of life, which reflects the fact that growing bone is most easily imprinted by nutritional disturbances and that children are at greatest risk of malnutrition (Huss-Ashmore et al. 1982). The presence of non-specific stress indicators such as LEH is the best indication of increased stress. LEH are particularly useful as they can be scored based on the severity and frequency of occurrences. Studies focusing on the confluence of multiple non-specific stressors have been used widely to asses a population’s well-being (Colli et al. 2009; Cucina 2002, 2010, 2012; Garcin et al. 2010; Goodman and Armelagros 1985; Halcrow and Tayles 2011; Harvey 2010; Hillson 1997; Prowse 2011; Sofar 2011; Wright 1997, 1999; Wheeler 2009; Zuckerman and Armelagros 2011).

Maya LEH Studies

Within the Maya region, LEH has been used to understand weaning, and to compare the health of populations over time and among different status groups. While burial populations with more stress as subadults seemed to die younger, researchers focusing on the Classic Maya did not find any correlation between early childhood stress and large numbers of young in their burial populations. That is, within the Classic Maya occupation, no definitive relationship between defects and age at death has been identified. Nor had any change in the amount of stress been identified during the transition from the Classic to the Late and Terminal Classic periods.

For example, Wright (1997) used Goodman and Rose's (1990) method in her study of Classic period Maya health to compare the incidence of hypoplastic defects among three periods: the Early, Late, and Terminal Classic at six sites within the Pasion River region of Guatemala. Her results show that there may not have been a decrease in overall population health in the Maya lowlands during the later portions of the Classic period (Wright 1997). However, she did find that a significant difference may occur in the timing of early childhood stress as related to weaning patterns, which appear to have changed over time. Wright’s findings are supported by Storey’s (1999) more general study of pathologies. A comparison of the occurrence of non-specific stressors in elite and non-elite/commoners at Copan, Honduras suggested that non-specific stress markers like porotic hyperostosis were expressed throughout all status groups and time periods.

Mendez Colli and colleagues (2009) further explore the correlation between the timing and frequency of early childhood stress and frailty in an attempt to explain the early life mortality observed in the burial population the Classic Maya site of Xcambo. They found an inverse relationship between age at death and the timing and frequency of early childhood stress. That is, when comparing subadults to adults, there is an increase in early childhood stress observed within the subadult group which was offered as a probable cause for the early childhood mortality rate at Xcambo.

Cucina (2011) further explored the correlation of early childhood stress to frailty by subdividing subadults into categories, including 4-9 year-olds and 10-19 year-olds, in the Xcambo sample. He found no discernible difference among age classes. Despite apparent differences between the subadult population and adult populations (Colli et al. 2009), Cucina (2011:114) felt that the inverse relationship between stress and age at death that appeared to link hypoplastic defects and mortality came from a variety of external factors that presented themselves after each individual surpassed the critical age of 5 years, such as infection, disease, and general illness that postdated the development period.

Adams (1998) explored the health of Xunantunich, a major Maya center in the eastern Maya lowlands located near the banks of the Mopan River in the Belize River Valley. Adams (1998) compared pathological conditions in the Xunantunich burial population with two rural communities nearby, San Lorenzo and Chaa Creek. Skeletal pathology among all sites showed that the populations were generally healthy with very few pathological manifestations of stress, disease, or malnutrition (Adams 1998:41). A comparison of enamel hypoplasia occurrences, however, showed a significant difference in mean age of disruption (Adams 1998:42). A difference of one year in the age of disruption was observed between the Xunantunich population (3.56 year) and the Chaa Creek one (4.45 years), which Adams attributed to a difference in the timing at which weaning occurred. While information on the number of observable hypoplasias per individual or the frequency at which enamel defects occurred is not available, Adams' (1998) results suggest that the variation in weaning patterns may be linked to cultural buffers within the Belize River Valley.

Scopa-Kelso (2004) also studied variation in enamel defects in and around Xunantunich. Her study focused on the variation in frequency and timing of enamel defects among the burial populations from Actuncan, Xunantunich, San Lorenzo, and Chaa Creek. All four sites are considered to have been participants in the same polity that clustered around the major center of Xunantunich during the Late Classic period (LeCount 2001; Scopa-Kelso 2004). Actuncan and Xunantunich are urban centers, while Chaa Creek and San Lorenzo are smaller rural communities. Evaluation of enamel defects suggests that children at the larger urban centers experienced stress at an older age than those in the rural communities. The frequency of occurrence at Actuncan and Xunantunich was found to be greater than that observed at Chaa Creek and San Lorenzo. Scopa-Kelso (2004) suggested that the increased frequency resulted from larger population size in urban centers, which may lead to an increased transmission of disease. Differences in age at defect among the burial populations could also relate to social and economic differences, as elites may have participated in longer weaning periods than the rural mothers who might have spent more time with larger workloads in the field that left less time for child rearing (Scopa-Kelso 2004:59).

These studies provide useful information for understanding how health during childhood reflected cultural practices and population frailty and mortality patterns in different Maya regions. Understanding childhood stress is a critical step in reconstructing the health of a population, and it may have differed among regions, especially during the Late and Terminal Classic periods. The next chapter details the analysis of hypoplastic defects at the inland site of Actuncan and the coastal sites of Chak Balam and San Juan on Ambergris Caye, Belize, to explore inter- and intra-site variance of early childhood health, frailty and mortality patterns. These sites have undergone previous analyses of pathologies; however, a number of new burials were recovered from Actuncan and previous LEH study has not been conducted for the Ambergris Caye burial population.

IV: METHODS AND RESULTS

Study of early childhood stressors such as linear enamel hypoplasias has been revitalized recently with the growing interest in juvenile bioarchaeology and mortuary analysis (Cucina 2002, 2012; Garcin et al. 2010; Harvey 2010; Lund 2003; Colli et al. 2009; Wright 1997, 1998, 1999, 2006; Wright and Chew 1998). Drawing from early works of Goodman and Rose (1980), bioarchaeologists have gained a greater understanding of the effect that significant early childhood stress has on longevity and population frailty. Many studies have focused on a given population (Cucina 2002, 2012) or a single region (Wright 1999), but I chose to compare coastal and inland sites in the eastern lowlands of modern-day Belize. A multifaceted variance analysis of early childhood stress and its relationship to an individual's age at death, at an intra-site as well as an inter-site level, shows a relationship between frequency of hypoplastic defects and frailty. This chapter details the methods used in the analysis and the relationship between early childhood stress and mortality in the Late and Terminal Classic coastal populations of San Juan and Chac Balam on Ambergris Caye and the inland population of Actuncan, Belize.

Methods

Macroscopic examination of non-occlusal tooth surfaces was conducted on 206 teeth from a total of 67 individuals from three sites. All individuals with teeth present from Actuncan and Ambergris Caye were selected for study. Individuals with an undetermined age at death were excluded. Likewise, all teeth that were not associated with a specific individual (i.e., loose teeth found in building fill) were also excluded from my sample. Twenty-one individuals from 20 burials were selected from Ambergris Caye sites and 11 individuals from 9 burials were selected from Actuncan's burial population. Individual age determinations were primarily based on biological analyses from Freiwald (2012) and Glassman (1995).

The highly fragmentary state and absence of sex determinant skeletal features for many individuals resulted in inconclusive estimation of both sex and age at death. Age estimations by Freiwald (2012) for Actuncan and Glassman (1995) for Ambergris sites were further analyzed using dental development and attrition (Moorees et al. 1963a; Ubelaker and Buikstra 1994:50) to determine more discrete age ranges. Individuals were separated into three age groups: 4-9 years, 10-19 years, and 20+ years old, using the mid-point of the individual's age range. For example, the mid-point for an individual estimated to be 13-17 years at the time of death is 15 years of age, which fits in the 10- to 19-year-old category.

Macroscopic identification of major growth arrests, or hypoplastic defects on the crown surface, was done under a combination of natural and artificial light, and stress markers were counted for each tooth with observable hypoplastic defects. When both the left and right teeth were present, only the antimere of a given maxillary or mandibular tooth with the highest rate and/or severity of observable hypoplasia was sampled to avoid double counting. Teeth were excluded if they exhibited heavy wear, obliteration of more than one-half the tooth crown (Cucina 2002, 2011), or showed occlusal wear that scored 4 or greater on the 1-8 scale (Ubelaker and Buikstra 1994:52). All fractured or incomplete tooth crowns were also excluded from this study.

The distance from the cementoenamel junction (CEJ) to the mid-point of each hypoplastic defect was measured to the nearest 0.01 mm using Mitituyo (ABSOLUTE 573-621) narrow tipped digital sliding calipers. Full crown heights taken from the CEJ to the cusp were recorded to control for attrition. Both the total crown heights and the locations of each hypoplastic defect were introduced into a regression formula to arrive at a mean age at defect for each individual tooth. The regression formula is based on analyses by Goodman et al. (1980), Goodman and Rose (1990), and Wright (1997). The original regression formula presented by Goodman and Rose (1990) was adapted by Wright (1997:238) to account for the age of the mandibular canines of a 4.5 year-old, which more accurately fits Amerindian populations. I further modified the regression formula to fit the age of initial enamel formation presented by Schneid and Weiss (2012), and built regression equations for the upper and lower third molar. However, due to the variability of formation times and limited sampling, I have excluded the third molars.

Regression Formula:

Age at formation = Age at crown completion - [(years of formation/complete crown height) x defect height]

This formula is based on the velocity of enamel growth (years from initial enamel secretion to crown completion) from the initial age of development (Goodman et al. 1980; Goodman and Rose 1990; Schneid and Weiss 2012; Wright 1997, 2006) and the mean crown height of completely formed teeth. Measurements of crown height (CEJ to the tooth cusp) of complete teeth from each tooth class were taken. Each measurement was then transferred to a regression formula for each population (Ambergris Caye sites and Actuncan) in order to control for population-specific crown growth (see Appendix A). The regression formula allows us to assess the age at which the hypoplastic defect occurred. All teeth with observable hypoplastic defects were selected from the collection for this analysis. The teeth were then separated into groups based on tooth class: upper and lower central incisors (I1), upper and lower lateral incisors (I2), upper canines (C), lower canines (LC), upper and lower first premolars (P3), upper and lower second premolars (P4), upper and lower first molars (M1), and upper and lower second molars (M2).

Statistical analysis was completed using Student's t-Test. I compared the mean age of disruption, the proportion of teeth affected by hypoplasias, and the mean number of hypoplasias per tooth across samples for each tooth type. I also compared hypoplastic disruptions among the three sites in the study and by age groups.

The results present a picture of childhood heath and frailty not only on an individual level, but at a population and regional level as well (Cucina 2012; Wright 1999). One goal of this thesis is to explore the relationship between the prevalence of enamel hypoplasias and the age at death. Observing the relationship between the two will lead to the larger question: does poor childhood health relate to increased frailty and potentially earlier death? If so, does this relationship exist on a regional scale? Alternatively, if no statistically significant relationship is found, what other factors might explain the difference between inland and coastal mortuary profiles?

Three hypotheses serve to test this relationship at the individual and the population levels:

Hypothesis #1 (Null): There is no statistically significant difference between the age at defect or number of defects when comparing the Actuncan and Ambergris Caye burial populations. The mean age at stress and the number of defects will be constant throughout the population as each age group will encounter the same amount of stress over time regardless of regional location. This also suggests that factors such as temporal distinctions, burial location, or status may be the primary explanation for the differences in the coastal and inland mortuary profiles.

Alternative Hypothesis: There is a significant difference between age groups when comparing age at defect and/or number of defects to age at death in the Ambergris and Actuncan populations. This suggests that early childhood stress is a plausible explanation for the discrepancy between the Actuncan and Ambergris mortuary profiles.

Hypothesis #2 (Null): There is no significant difference between the age at defect or the number of defects among age groups in the two burial populations, San Juan and Chac Balam, of Ambergris Caye. The mean age at stress and the number of defects will be constant throughout the population as each age group will encounter the same amount of stress over time.

Alternative Hypothesis: There is a significant difference among age groups when comparing the age at defect or number of defects to age at death within the Ambergris population. This suggests that differences may be present in weaning practices, health stressors, and/or cultural buffers to childhood stress within the coastal region.

Hypothesis #3 (Null): There is no significant difference between the age at defect or number of defects among age groups within the Actuncan population. The mean age at stress and the number of defects will be constant throughout the population as each age group will encounter the same amount of stress over time.

Alternative Hypothesis: There is a significant difference among age groups when comparing age at defect or number of defects to age at death within the Actuncan population. This suggests differences in the factors presented in alternative Hypothesis #2 as opposed to those factors presented in Hypothesis #1.

The results show that we must fail to reject the Hypothesis #1. While differences can be observed, they are not statistically significant enough to account for the discrepancy in the mortality profiles. Alternatively we can reject Hypotheses #2 and 3. Statistically significant results show that within both populations there is an inverse relationship between age at death and early childhood stress. This data are presented below.

Results

The first analysis assessed the relationship between the number and timing of enamel defects and age at death of adults and subadults at the intra-site level. Variation in the timing and severity of childhood stress has been noted amongst the Maya (Cucina 2002, 2010, 2012; Harvey 2011; Colli et al. 2009; Storey 1999; Wright 1997, 2006) and relate to changes in diet and severity of nutritional and/or metabolic stress. Significant differences suggest that increased stress at an early age will decrease an individual's wellbeing, as well as life expectancy (Cucina 2002, 2011, 2012; Harvey 2011; Colli et al. 2009; Storey 1999; Wright 1997, 2006). The intra-site analysis shows an inverse relationship between the early childhood stress and age at death in both the coastal and inland regions of the eastern Maya lowlands.

Equivalent analysis was conducted at an inter-site level upon competition of the intra-site analysis for each population. The inter-site analysis was carried out in order to see if variation in childhood stress between the coastal and inland populations could account for the regional variation between the two mortuary profiles. This shows that the inland population of Actuncan may have had a larger amount of stress overall compared to the island sites from the Ambergris Caye.

Ambergris Caye Intra-site Analysis

Analysis of the coastal burial population shows a relationship between the age of early childhood stress and the age at death in the burial population of Ambergris Caye. The Student's t-Test shows a statistically significant relationship in the age at defect in the third premolar and in the average number of defects in the lower canine, third and fourth premolars, and first molar tooth types. That is, individuals who died as juveniles had more stress at an earlier age than those who survived into adulthood. However, there were no significant differences in most teeth in a direct comparison of subadults to adults. The following discussion provides a detailed analysis of the Linear Enamel Hypoplasia (LEH) data and what it suggests about the health of Classic period Ambergris Caye populations.

I first compared the mean age at defect observed in incisors, canines, premolars and molars of individuals who died before the age of 20 (subadults) and those who survived into adulthood (20 + years). There is a significantly younger age at disruption in subadult third premolars (mean 3.90 years, $p = .037$) (Table 3). Likewise, the mean number of stress episodes was significantly greater for subadults in two teeth: the lower canine ($p = .095$) and fourth premolar ($p = .050$) (Table 4). The significant difference that was observed between the subadult and adult individuals was further explored by separating the subadult class into two independent classes (4-9 years and 10-19 years of age). Comparison of the age classes (4-9 years vs. 10-19 years, 4-9 years vs. adults and 10-19 years vs. adult) allows for a more specific interpretation as to the influence that early childhood stress played during different periods in life. The 4-9 year age class exhibited more stress episodes at an earlier age than their older counterparts.

Table 3. Ambergris intra-site: comparing the mean age at defect between subadults and adults

	Ambergris Age at Defect				Student's t-Test	
	Subadult		Adult		Subadult vs. Adult	
Tooth	**mean**	**N**	**mean**	**N**	**t**	**p**
I1	2.97	10	3.26	8	-1.547	0.142
I2	3.17	11	3.38	9	-0.798	0.435
C	4.13	5	4.30	7	-0.496	0.63
LC	3.23	4	3.39	9	-1.519	0.157
P3	3.90	7	4.53	10	**-2.252**	**0.037**
P4	4.99	7	5.16	11	-0.471	0.643
M1	2.38	9	2.56	13	-1.579	0.13
M2	1.60	5	2.00	5	-1.000	0.347

Values of t in **bold** are significant at $p \leq 0.10$
Values of t in **bold underline** are significant at $p \leq 0.05$

Table 4. Ambergris intra-site: comparing the mean number of defects between subadults and adults

	Ambergris Mean Number of Defects				Student's t-Test	
	Subadult		Adult		Subadult vs. Adult	
Tooth	**mean**	**N**	**mean**	**N**	**t**	**p**
I1	2.60	10	2.50	8	0.144	0.887
I2	2.73	11	2.77	9	-0.094	0.926
C	3.40	5	2.57	7	1.702	0.12
LC	3.75	4	2.66	9	**1.824**	**0.095**
P3	2.43	7	1.84	13	1.561	0.136
P4	2.29	7	1.58	12	**2.108**	**0.05**
M1	2.33	9	1.85	13	1.469	0.157
M2	1.66	6	1.71	7	-0.130	0.899

Values of t in **bold** are significant at $p \leq 0.10$
Values of t in **bold underline** are significant at $p \leq 0.05$

When compared to the 10-19 year age group, the 4-9 year group has an earlier age of overall stress present on the I1 at 2.58 years (p = .046) and M1 at 2.12 years (p = .090). The difference in timing is approximately one-half year earlier in the youngest population. Earlier exposure to stress is more apparent in the 4- to 9-year-old group as compared to the adult groups. The I1 (p = .015), P3 (p = .042), and M1 (p = .063) tooth types display a significant difference in timing that is on average 3/4 to one full year earlier (Table 5). Mean age at stress for the 10-19 year age group was observed, but much less pronounced, when compared to the adult individuals. A significant difference is present in only the P3 (4.02 years p = .095) tooth type (Table 5).

Table 5. Ambergris intra-site: Student's t-Test comparing the mean age at defect between all age groups (Full table in Appendix B)

	Student's t-Test					
	4-9 yrs vs. 10-19 yrs		10-19 yrs vs. Adult		4-9 yrs vs. Adult	
Tooth	**t**	**p**	**t**	**p**	**t**	**p**
I1	**-2.36**	**0.046**	-0.731	0.478	**-2.985**	**0.015**
I2	-1.22	0.254	-0.289	0.776	-1.388	0.195
C	-0.25	0.820	-0.347	0.737	-0.502	0.634
LC	-	-	-1.519	0.157	-	-
P3	-1.30	0.251	**-1.766**	**0.095**	**-2.272**	**0.042**
P4	-	-	-0.471	0.643	-	-
M1	**-1.96**	**0.090**	-0.923	0.368	**-2.036**	**0.063**
M2	-	-	-0.044	0.966	-	-

Values of t in **bold** are significant at $p \leq 0.10$
Values of t in **bold underline** are significant at $p \leq 0.05$

The frequency of early childhood stress is similar to the mean age at stress endured by individual age groups (Table 6). While they are not as pronounced as variations in the age of occurrence, there remains a distinguishable relationship between the mean number of stress episodes and the age at death within the Ambergris burial population. The 4-9 year age group has a higher frequency of stress on the I2 (p = .020) tooth class when compared to the 10-19 year age group, and a higher frequency observed on the M1s (p = .039) than those from the adult age group (Table 6). These tooth classes are evidence of stress occurring not only more frequently, but also earlier in the 4-9 year age group than in their the adult counterparts. This may be explained by the development of the I2 and M1 teeth, which begins at or around the time of birth. The same trend is apparent when comparing the frequency of stress of the 10-19 year age group to the adult class. Observation of the LC (p = .095) and P4 (p = .050) tooth classes of these subadults show significantly more stress occurrences than those of the adult individuals (Table 6), with significant differences occurring in higher frequencies in the tooth classes that are occurring a few years after that of the 4-9 year age group. That is, there is a significantly earlier age at stress relative to age at death when comparing age groups.

Table 6. Ambergris intra-site: Student's t-Test comparing the mean number of defects between all age groups (Full table in Appendix B)

	Student's t-Test					
	4-9 yrs vs. 10-19yrs		10-19 yrs vs. Adult		4-9 yrs vs. Adult	
Tooth	**t**	**p**	**t**	**p**	**t**	**p**
I1	0.556	0.593	-0.098	0.923	0.452	0.662
I2	**<u>2.832</u>**	**<u>0.020</u>**	-1.019	0.325	1.575	0.146
C	-0.755	0.495	1.715	0.120	0.411	0.695
LC	**-**	**-**	**1.824**	**0.095**	-	-
P3	-0.441	0.677	1.633	0.121	0.215	0.833
P4	-	-	**<u>2.108</u>**	**<u>0.050</u>**	-	-
M1	1.283	0.240	0.827	0.419	**<u>2.296</u>**	**<u>0.039</u>**
M2	-	-	-0.130	0.899	-	-

Values of t in **bold** are significant at $p \leq 0.10$
Values of t in **<u>bold underline</u>** are significant at $p \leq 0.05$

In sum, these differences suggest that the large number of stressors observed in the Ambergris population is representative of early childhood stress as a catalyst for increased frailty and mortality among the younger individuals. However, while this may be true for the island sites on the Ambergris Caye, the Actuncan population does not show the same significant difference in the age of stress occurrence between age groups. Instead, a significant difference is only present in the frequency of defects observed at Actuncan, which is described in detail in the following section.

Actuncan Intra-site Analysis

Intra-site analysis was also conducted for the Actuncan burial population following the same method as the Ambergris Caye population. Cross tabulation of age groups and the age at defect in the inland population of Actuncan showed no significant difference in the timing of stress in either subadults versus adults or the comparison between different age groups (Table 7 and 8). This illustrates that stress patterns such as weaning, at least by age of occurrence, remained more or less the same throughout the occupation of Actuncan from the Preclassic to Terminal Classic periods. However, a significant difference is observed between subadults and adults when comparing the number of stress episodes.

Table 7. Actuncan intra-site: comparing the mean age at defect among subadult and adults

	Actuncan age of defects				Student's t-Test	
	Subadult		Adult		Subadult vs. Adult	
Tooth	**mean**	**N**	**mean**	**N**	**t**	**p**
I1	3.14	4	2.75	6	0.88	0.406
I2	2.80	6	3.25	7	-1.34	0.208
C	3.37	2	3.90	5	-1.16	0.300
LC	3.00	2	2.68	3	0.82	0.474
P3	4.35	6	4.58	9	-0.75	0.469
P4	5.06	2	5.30	4	-0.26	0.808
M1	2.38	4	2.61	4	-0.59	0.578
M2	6.15	2	6.25	5	-0.40	0.708

Values of t in **bold** are significant at $p \leq 0.10$
Values of t in **<u>bold underline</u>** are significant at $p \leq 0.05$

Table 8. Actuncan intra-site: Student's t-Test comparing the mean age at defect between all age groups (Full table in Appendix B)

	Student's t-Test					
	4-9 yrs vs. 10-19yrs		10-19 yrs vs. Adult		4-9 yrs vs. Adult	
Tooth	**t**	**p**	**t**	**p**	**t**	**p**
I1	-0.425	0.712	0.84	0.426	0.274	0.795
I2	0.751	0.495	-1.52	0.159	0.048	0.964
C	-	-	-1.16	0.300	-	-
LC	-	-	0.82	0.474	-	-
P3	-	-	-0.75	0.469	-	-
P4	-	-	-0.26	0.808	-	-
M1	-1.116	0.381	0.38	0.723	-1.207	0.294
M2	-	-	-0.40	0.708	-	-

Values of t in **bold** are significant at $p \leq 0.10$
Values of t in **<u>bold underline</u>** are significant at $p \leq 0.05$

The number of stress episodes observed in the subadult population is nearly double their adult counterparts for the P3, P4, and M2 tooth types (Table 9). All are significant at the 95% confidence level (P3 *p* .000, P4 *p* .026, M2 *p* .016). Separating the subadult category into two respective classes (4-9 and 10-19 years of ages) shows a significant increase in hypoplastic defects occurring in the 10-19 year age group in most tooth types (I1, I2, P3, P4, and M2) as compared to adults (Table 10). Though the relationship shows that stress was more frequent within the 10-19 year age range, the significance present in the 10-19 year range compared to the 4-9 year age range may be due to the small sample size. Significant differences were observed in comparisons between all age groups age groups at Actuncan, but the differences between the 10-19 year classification and 20+ year category suggests that the frequency of early childhood stress is more prevalent in those with an earlier mortality.

Table 9. Actuncan intra-site: Student's t-Test comparing the mean number of defect between subadult and adults

	Actuncan Mean Number of Defects				Student's t-Test	
	Subadult		Adult		Subadult vs. Adult	
Tooth	**mean**	**N**	**mean**	**N**	**t**	**p**
I1	4.25	4	2.83	6	1.824	0.106
I2	3.50	6	2.71	7	1.779	0.103
C	4.50	2	3.20	5	1.139	0.306
LC	3.00	2	2.66	3	0.293	0.789
P3	3.83	6	1.88	9	<u>**5.561**</u>	<u>**0.000**</u>
P4	3.00	2	1.50	4	<u>**3.464**</u>	<u>**0.026**</u>
M1	2.00	4	2.00	4	0.000	1.000
M2	3.00	2	1.80	5	<u>**3.586**</u>	<u>**0.016**</u>

Values of t in **bold** are significant at $p \leq 0.10$

Values of t in <u>**bold underline**</u> are significant at $p \leq 0.05$

Table 10. Actuncan intra-site: Student's t-Test comparing the mean number of defects among all age groups (Full table in Appendix B)

	Student's t-Test					
	4-9 yrs vs. 10-19yrs		10-19 yrs vs. Adult		4-9 yrs vs. Adult	
Tooth	**t**	**p**	**t**	**p**	**t**	**p**
I1	-	-	<u>**3.688**</u>	<u>**0.008**</u>	-0.785	0.468
I2	<u>**-3.740**</u>	<u>**0.021**</u>	<u>**2.851**</u>	<u>**0.17**</u>	-0.884	0.411
C	-	-	1.139	0.306	-	-
LC	-	-	0.293	0.789	-	-
P3	-	-	<u>**5.561**</u>	<u>**0.000**</u>	-	-
P4	-	-	<u>**3.464**</u>	<u>**0.026**</u>	-	-
M1	-1.414	0.293	1.633	0.178	-1.633	0.178
M2	-	-	<u>**3.586**</u>	<u>**0.016**</u>	-	-

Values of t in **bold** are significant at $p \leq 0.10$

Values of t in <u>**bold underline**</u> are significant at $p \leq 0.05$

Intra-site analysis conducted for both the Ambergris Caye and Actuncan populations suggests that while difference in timing may not be significant, chronic or increased frequency in episodic stress over time may impact individuals' overall well-being. Further analysis was conducted with an inter-site comparison in order to determine whether or not these differences in early life stressors may account for the variation of mortuary profiles on a regional scale.

Inter-site Analysis

A comparison of coastal and inland sites included the age of occurrence and the frequency of stress between the burial populations in each eastern Maya lowland region. The mean age at stress shows a significantly earlier disruption in Actuncan maxillary (p = .091) and mandibular (p = .001) canine teeth (Table 11). As for the number of stress occurrences, the Actuncan population shows a higher frequency of stress in the P3 (p = .086) tooth type (Table 12). The differences observed in these burial populations were further examined by comparing the age at stress and the frequency of occurrence among age groups between sites.

Table 11. Inter-site: comparing the mean age at defect between inland and coastal populations

	Ambergris		Actuncan		Student's t-Test	
Tooth	**mean**	**N**	**mean**	**N**	**t**	**p**
I1	3.10	18	2.90	10	0.980	0.336
I2	3.26	20	3.04	13	1.046	0.303
C	4.23	12	3.75	7	**1.793**	**0.091**
LC	3.34	13	2.81	5	<u>**3.896**</u>	<u>**0.001**</u>
P3	4.31	20	4.49	15	-0.850	0.401
P4	5.09	19	5.22	6	-0.338	0.739
M1	2.49	22	2.43	8	-0.045	0.964
M2	5.96	13	6.23	7	-1.920	0.071

Values of t in **bold** are significant at $p \leq 0.10$
Values of t in <u>**bold underline**</u> are significant at $p \leq 0.05$

Table 12. Inter-site: comparing the mean number of defects between inland and coastal populations

	Ambergris		Actuncan		Student's t-Test	
Tooth	**mean**	**N**	**mean**	**N**	**t**	**p**
I1	2.55	18	3.40	10	-1.531	0.138
I2	2.75	20	3.08	13	-0.868	0.392
C	2.91	11	3.57	7	-1.207	0.245
LC	3.00	13	2.80	5	0.351	0.730
P3	2.05	19	2.66	15	**-1.770**	**0.086**
P4	1.84	19	2.00	6	-0.424	0.675
M1	2.05	22	2.00	8	0.151	0.881
M2	1.69	13	2.14	7	-1.476	0.157

Values of t in **bold** are significant at $p \leq 0.10$
Values of t in **bold underline** are significant at $p \leq 0.05$

The age at occurrence comparison between subadults (<20 years) at Ambergris Caye and those at Actuncan showed an earlier age of stress on the M1 tooth type (p = .009) for the coastal population. All other tooth types did not show any significant difference for the mean age at stress (Table 13). When comparing the adult (20 + years) populations, there was an earlier age at stress observed in the lower canines (p = .001). Again, all other tooth types were devoid of any significant difference in mean age at stress occurrence (Table 14). Age at stress in the 4- to 9-year-old coastal population was observed in the M1 tooth class (p = .062), while 10- to 19-year-old age group shows an inland population with an early average age at stress within the I2 (p = .092) tooth class (Table 15). No significant difference in mean age of stress was observed for any other tooth class among the age at death ranges.

Table 13. Inter-site: comparing the mean age at defect between subadults

	Inter-site Subadult Mean Age at Defect					
	Ambergris		Actuncan		Student's t-Test	
Tooth	**mean**	**N**	**mean**	**N**	**t**	**p**
I1	2.97	10	3.14	4	-0.61	0.552
I2	3.17	11	2.80	6	1.15	0.267
C	4.17	4	3.37	2	1.42	0.23
LC	3.23	4	3.00	2	0.92	0.412
P3	4.02	6	4.35	6	-1.01	0.337
P4	4.99	7	5.06	2	-0.15	0.882
M1	2.38	9	3.94	4	**-3.14**	**0.009**
M2	5.96	6	6.15	2	-0.86	0.424

Values of t in **bold** are significant at $p \leq 0.10$
Values of t in **bold underline** are significant at $p \leq 0.05$

Table 14. Inter-site: Student's t-Test comparing the mean age at defect between adults

.	Inter-site Adult Mean Age at Defect					
	Ambergris		Actuncan		Student's t-Test	
Tooth	**mean**	**N**	**mean**	**N**	**t**	**p**
I1	3.26	8	2.75	6	1.685	0.118
I2	3.38	9	3.25	7	0.468	0.647
C	4.30	7	3.90	5	1.207	0.225
LC	3.39	9	2.68	3	**4.538**	**0.001**
P3	4.53	13	4.58	9	-0.212	0.835
P4	5.16	12	5.30	4	-0.269	0.792
M1	2.56	13	2.61	4	-0.251	0.805
M2	5.97	7	6.25	5	-1.510	0.162

Values of t in **bold** are significant at $p \leq 0.10$
Values of t in **bold underline** are significant at $p \leq 0.05$

Table 15. Inter-site: Student's t-Test comparing the mean age at defect between all age groups

	Students's t-Test					
	4-9 yrs		10-19 yrs		Adult	
Tooth	**t**	**p**	**t**	**p**	**t**	**p**
I1	-0.652	0.581	-0.09	0.932	1.685	0.118
I2	-0.453	0.695	**1.85**	**0.092**	0.468	0.647
C	-	-	1.42	0.23	1.207	0.225
LC	-	-	0.92	0.412	**<u>4.538</u>**	**<u>0.001</u>**
P3	-	-	-1.01	0.337	-0.212	0.835
P4	-	-	-0.15	0.882	-0.269	0.792
M1	**-3.822**	**0.062**	-1.76	0.121	-0.251	0.805
M2	-	-	-0.86	0.424	-1.510	0.162

Values of t in **bold** are significant at p ≤ 0.10
Values of t in **<u>bold underline</u>** are significant at p ≤ 0.05

Inter-site mean number results

I further explored the mean number of defects observed in Table 12 by subdividing the burial populations into respective age at death ranges in order to fully outline the distribution of stress episodes in correlation to the age at death. While no significant frequency of stress was observed between the adult groups at these inland and coastal sites, there was a significant difference between the subadult groups. The inland population at Actuncan exhibited a greater frequency of stress episodes in the I1 (p = .078), P3 (p = .016), and M2 (p = .019) tooth types (Table 16). The trend observed in Table 16 was also present in the 10-19 year age comparison using the same teeth (I1: p = .010, P3: p = .016, M2: p = .019). The only difference in Table 17 was the significance in a comparison of the 4-9 year M1 tooth type. Comparison of the youngest age range shows that the frequency of stress during the growth period of the first molar was elevated in the coastal population (p = .095). A difference is also observed for the I1 and I2 tooth classes, when comparing the youngest age class; however, this difference is not statistically significant (Tables 16 and 17).

Table 16. Inter-site: comparing the mean number of defects between all age groups coastal and inland subadults and adults

	Inter-site Mean Number of Defects						Student's t-Test			
	Ambergris			Actuncan			Subadult		Adult	
	Subadult		Adult	Subadult		Adult				
Tooth	**mean**		**mean**	**mean**		**mean**	**t**	**p**	**t**	**p**
I1	2.60	10	2.50	4.25	4	2.83	**-1.927**	**0.078**	-0.468	0.648
I2	2.72	11	2.77	3.50	6	2.71	-1.402	0.181	0.112	0.905
C	3.50	4	2.57	4.50	2	3.20	-1.886	0.132	-0.891	0.394
LC	3.75	4	2.66	3.00	2	2.66	0.667	0.541	0.000	1.000
P3	2.50	6	1.85	3.83	6	1.89	<u>**-2.902**</u>	<u>**0.016**</u>	-0.135	0.894
P4	2.28	7	1.58	3.00	2	1.50	-1.273	0.244	0.222	0.827
M1	2.33	9	1.85	2.00	4	2.00	0.650	0.529	-0.437	0.668
M2	1.60	6	1.71	3.00	2	1.80	<u>**-3.416**</u>	<u>**0.019**</u>	-0.225	0.826

Values of t in **bold** are significant at $p \leq 0.10$

Values of t in <u>**bold underline**</u> are significant at $p \leq 0.05$

Table 17. Inter-site: Student's t-Test comparing the mean number of defects between all age groups (Full table in Appendix B)

	Student's t-Test					
	4-9 yrs		10-19 yrs		Adult	
Tooth	**t**	**p**	**t**	**p**	**t**	**p**
I1	0.433	0.707	**-3.382**	**0.010**	-0.468	0.648
I2	1.732	0.225	-3.593	0.004	0.112	0.905
C	-	-	-1.886	0.132	-0.891	0.394
LC	-	-	0.667	0.541	0.000	1.000
P3	-	-	**-2.902**	**0.016**	-0.135	0.894
P4	-	-	-1.273	0.244	0.222	0.827
M1	**3.000**	**0.095**	-0.509	0.626	-0.437	0.668
M2	-	-	**-3.416**	**0.019**	-0.225	0.826

Values of t in **bold** are significant at $p \leq 0.10$

Values of t in **bold underline** are significant at $p \leq 0.05$

Conclusion

Intra-site analysis of both Ambergris Caye and Actuncan populations show that earlier and more frequent occurrence of early childhood stress is inversely related to individual's age at death. The Ambergris Caye population shows the most significant differences in stress between the youngest age group and the adult individuals. This trend continues throughout comparison of respective age groups showing a significant relationship between the amount of stress and age at death (Tables 5 and 6). This may be due to a shift in weaning patterns or earlier independence between the adults and the youngest age group (Scopa-Kelso 2004; Storey 2002; Wright 1997, 2006). As for the Actuncan population, no significant change is present when comparing the timing of stress occurrence between age groups, although the frequency of stress in younger age groups is apparent (Table 10). There is a significant inverse relationship between stress and age at death on an intra-site level for both populations. However, further exploration of the regional variability of early childhood stress and mortuary profiles suggests that there is no significant difference between inland or coastal sites.

While observable differences between the subadult groups are present on an inter-site level, it is not possible to attribute the difference in mortuary profiles to early childhood stress. The Actuncan subadult population as a whole has significantly more defects in all subadult classes than the Ambergris Caye population. However, definitive conclusions may only be drawn from the 10-19 year age range. This is due to opposing differences observed when comparison of the 4-9 year age group between sites. Significantly earlier and more frequent occurrence of stress is present in the coastal M1 tooth class in 4-9 year age groups. A similar trend is present for the I1 and I2 tooth types, though the differences are not statistically significant (Tables 15 and 17).

This suggests that the coastal population from the Ambergris Caye was in fact subject to increased stress in the earliest age group, explaining the greater number of subadults in the coastal burial population and the different mortuary profiles. However, the significant differences expressed between the youngest age groups at Actuncan and Ambergris Caye is most likely due to the limited sample size from the Actuncan skeletal population. Due to the limited subadult sample from Actuncan, these trends can neither be confirmed nor denied. In sum, difference in mortality profiles of the island population at Ambergris Caye and the inland population of Actuncan cannot be attributed to early childhood stress indicators at this time.

V: CONCLUSION AND DISCUSSION

Since the late 1980s, an inverse relationship between early childhood stress and decreased longevity has been reported in prehistoric populations (Goodman and Armelagros 1985; Duray 1996; Colli et al. 2009; Storey 1997, 2002). The increase in stress at an early age of development can put an individual at a higher risk of early mortality. The result of this study has further substantiated this relationship on an inter-site level. For both hypothesis 2 and 3, we reject the null hypothesis as there is a significantly higher incidence of childhood stress in those individuals that succumbed to increased childhood morbidity. However, when comparing all samples, there is a failure to reject the null hypothesis 1. The significant differences are not strong enough to affirm early childhood stress as a explanation in the regional differences in mortuary profiles.

Inter-site analysis from Ambergris Caye (Tables 3-6) and Actuncan (Table 6-10) populations show that the frequency of early childhood stress is related to early mortality. Significant differences in the number of hypoplastic defects have shown that increased childhood stress was more frequent in the younger age groups in the Ambergris Caye sites, as well as in the Actuncan population. The increased frequency of stress sustained by the younger children in each population suggests that early childhood stress for each site was significant enough to increase frailty, in turn decreasing survivability into adulthood. These findings differ from those of Cucina (2011) at Xcambo as the significance in the number of hypoplastic defects continually increased as age at death decreased. Null hypotheses #2 and #3 can be rejected as there were significant increases in stress observed in subadult individuals in each population when compared to their adult counterparts.

Intra-site analysis of this thesis is congruent with findings by Cucina (2011) and Wright (1997, 2006) that significance in the decreased age at initial disruption does not have a substantial impact on an individual's longevity. The findings show that the Actuncan population had an earlier initial age at defect when compared to the Ambergris population. This may reflect a cultural shift in an early age of dependence or weaning period in the subadults (Colli et al. 2009; Cucina 2002; May et al. 1993; Wright 1997, 2006) or may be due to nutritional differences with the introduction of solid foods during or just following the end of weaning (Scopa-Kelso 2004; Storey 2002; Wright 1997, 2006).

There are several possible explanations for the differences stemming from dietary studies. The burial population at Actuncan may exhibit an earlier weaning age than the Ambergris populations, as the urban environment allows for longer periods of child rearing than in rural areas where women may have been more devoted to subsistence work (Scopa-Kelso 2004). It is also possible that individuals at Actuncan may have been more reliant on maize consumption during the introduction of solid foods during the weaning process. The primary diet for the Ambergris Caye populations came from marine resources, according to carbon and nitrogen analyses of bone collagen (Parker 2011). Similar isotopic dietary information is not currently available for Actuncan. The initial stress may be earlier, but no effect of the wellbeing or longevity can be substantiated. However, the frequency of defects tells another tale.

The higher frequency of enamel defects observed in the Actuncan population as compared to the Ambergris Caye is congruent with previous studies that observed an increased susceptibility to early childhood stress at larger centers (Danforth 1997; Scopa-Kelso 2004;

Storey 2002; Wright 1997, 2006). Although the Actuncan population exhibits a higher frequency of enamel defects when compared to the Ambergris Caye populations as a whole, the significance observed may only be due a limited sample size form Actuncan. When comparing the subadult age classes across sites there is an observable increased frequency of stress in the Ambergris Caye's youngest age group when compared to Actuncan. However, the differences observed between the youngest age groups cannot not be confirmed because they are not statistically significant.

The osteological paradox proposes that individuals who do not exhibit any pathological conditions are representative of those who died before the disease or related stress affected skeletal elements (Wood et al. 1992). That is, some individuals die due to poor health before they sustain any pathological markers in tooth or bone. The data in this thesis refute this statement: all age classes have exhibited LEH, and those in the younger subsets have shown a significantly higher number of stressor as compared to those in older ones. However, an issue does arise within the representation of each population and the generalized health as a whole; this study cannot take into account all individuals within the burial population. Dental remains from a number of individuals were not recovered during excavation; therefore, these individuals were not included nor could those individuals that were not able to be assigned an age.

This thesis has evaluated physiological stress occurrences during the developmental period of life and the regional variance of mortuary profiles based on early childhood stress and frailty between the coastal populations from the Ambergris Caye and the inland population of Actuncan. While significant differences were observed when comparing sites, this information is not strong enough to conclude that early childhood stress is directly associated with regional variation of mortuary profiles. A larger sample size would allow for a more confident assessment of the role that early childhood stress plays in the variance of mortuary profiles. Also comparing with other regions would allow for a more complete picture of regional variation of health across the Maya region.

Discussion

This study gives us an understanding of health from two differing environmental locations within the Maya lowlands. These two sites are very similar as they are both smaller centers which interact with larger centers through trade and quite possibly socio-political structure. The mortuary profiles, however, are quite different. Though the health patterns studied above do not account for the variance in health between the sites, I offer a few possible explanations of why these burial populations differ for future research.

During the Late and Terminal Classic period, the trade route along the eastern coast of Belize was being used heavily. This may have allowed the Ambergris Caye population to provide a more diverse food selection for their community. However, this could have also increased their susceptibility of communicable disease. While the younger individuals may look healthier when focusing on skeletal markers of disease, it is possible that bacterial and viral diseases spread rapidly throughout the community and left no markers on the skeletal elements. Also, Actuncan may have undergone increased stress as residents of the site participated in conflict identified in the central Peten region during the Late and Terminal Classic. The increase in stress among the middle age group could reflect the sociopolitical stress at the time.

On the other hand, the low number of subadults available for study from the inland population presents a question: Where are the children? Actuncan and the rest of the BRV seem to have incomplete burial populations with low numbers of infants and children.. Recent work in the Maya area has been focused on the use of ritual areas, such as caves and rock shelters which may have served as cemeteries. These ritual areas would have been harder to access for those in the coastal environments, especially on the Ambergris Caye. Relocation of individuals to a necropolis off of the island, as well as staking claim to land in the interior may have been difficult during the Late and Terminal Classic periods.

In all, research in the Maya region during the Classic period continues to reveal new questions, especially during the Late and Terminal periods. Continual aggregation of research is needed to answer these questions and fully understand key aspects of Maya life, such as health and morbidity. Further research with samples from the entirety of the Maya lowland region would be helpful in forming a complete analysis of health for both adults and children. Also, incorporating more recent studies of mortuary practice within the biological reconstruction of burial assemblages would help to resolve some of the shortcomings of microscopic studies of health and mortality profiles and open up a more holistic interpretation of Maya mortuary profiles.

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LIST OF APPENDENCES

APPENDIX A: REGRESSION TABLES

TABLE A.1: REGRESSION TABLE FOR ALL TEETH AMBERGRIS POPULATION

	Unworn Crown Height			Developmental age		
Tooth	**Mean***	**s.d.**	**N**	**at Cusp**	**at CEJ**	**Regression Equations****
Maxillary						
I^1	11.24	0.65	10	1.0	4.5	Age = -0.311x + 4.5
I^2	10.86	0.23	8	2.0	4.5	Age = -0.230x + 4.5
C	11.72	1.06	9	1.0	6.0	Age = -0.427x + 6.0
P^3	7.95	1.00	12	2.0	6.0	Age = -0.503x + 6.0
P^4	7.34	0.41	11	3.0	6.0	Age = -0.409x + 6.0
M^1	7.45	0.72	16	1.0	3.5	Age = -0.336x + 3.5
M^2	7.33	0.32	8	4.0	7.5	Age = -0.477x + 7.5
M^3	6.23	0.69	7	10.0	16.0	Age = -0.963x + 16.0
Mandibular						
I_1	9.63	0.65	9	1.0	4.0	Age = -0.311x + 4.0
I_2	9.73	1.20	9	1.0	4.0	Age = -0.308x + 4.0
LC	10.85	1.10	8	1.0	4.5	Age = -0.323x + 4.5
P_3	8.45	0.57	13	2.0	6.0	Age = -0.473x + 6.0
P_4	7.48	0.62	14	2.5	7.0	Age = -0.602x + 7.0
M_1	7.65	0.54	16	1.0	3.5	Age = -0.328x + 3.5
M_2	7.16	0.53	19	4.0	7.0	Age = -0.419x + 7.0
M_3	6.05	0.95	10	11.0	16.0	Age = -0.826x + 16.0

*All measurements taken in mm, and all ages calculated in years

**Where x equals the distance of the hypoplasia from the cemento-enamel junction

TABLE A.2 REGRESSION TABLE FOR ALL TEETH ACTUNCAN POPULATION

	Unworn Crown Height			Developmental age		
Tooth	**Mean***	**s.d.**	**N**	**at Cusp**	**at CEJ**	**Regression Equations****
Maxillary						
I^1	11.50	0.33	7	1.0	4.5	Age = -0.304x + 4.5
I^2	10.46	0.68	4	2.0	4.5	Age = -0.239x + 4.5
C	10.99	0.76	8	1.0	6.0	Age = -0.455x + 6.0
P^3	8.40	1.25	10	2.0	6.0	Age = -0.476x + 6.0
P^4	7.89	0.84	8	3.0	6.0	Age = -0.380x + 6.0
M^1	7.40	0.73	5	1.0	3.5	Age = -0.338x + 3.5
M^2	7.11	0.49	2	4.0	7.5	Age = -0.492x + 7.5
M^3	7.33	0.39	3	10.0	16.0	Age = -0.818x + 16.0
Mandibular						
I_1	8.36	0.25	2	1.0	4.0	Age = -0.419x + 4.0
I_2	9.67	0.59	5	1.0	4.0	Age = -0.359x + 4.0
LC	10.74	0.30	2	1.0	4.5	Age = -0.326x + 4.5
P_3	8.77	0.97	7	2.0	6.0	Age = -0.456x + 6.0
P_4	8.25	0.61	4	2.5	7.0	Age = -0.545x + 7.0
M_1	7.88	0.33	3	1.0	3.5	Age = -0.317x + 3.5
M_2	7.56	0.23	2	4.0	7.0	Age = -0.399x + 7.0
M_3	7.29	0.00	1	11.0	16.0	Age = -0.686x + 16.0

*All measurements taken in mm, and all ages calculated in years

**Where x equals the distance of the hypoplasia from the cemento-enamel junction

APPENDIX B: UNABRIDGED TABLES

Table 3 (Unabridged): Ambergris Intra-Site: Student's t-Test comparing the mean age at defect between all age groups.

	Ambergris Intra-site Age at Defect						Student's t-Test					
	Subadult				Adult							
	4-9 yrs		10-19 yrs		20+ yrs		4-9 yrs vs. 10-19yrs		10-19 yrs vs. Adult		4-9 yrs vs. Adult	
Tooth	**Mean**	**N**	**mean**	**N**	**mean**	**N**	**t**	**p**	**t**	**p**	**t**	**p**
I1	2.58	3	3.17	7	3.26	8	**-2.36**	**0.046**	-0.731	0.478	**-2.985**	**0.015**
I2	2.81	3	3.31	8	3.38	9	-1.22	0.254	-0.289	0.776	-1.388	0.195
C	3.98	1	4.17	4	4.30	7	-0.25	0.820	-0.347	0.737	-0.502	0.634
LC	-	-	3.23	4	3.39	9	-	-	-1.519	0.157	-	-
P3	3.18	1	4.02	6	4.53	13	-1.30	0.251	**-1.766**	**0.095**	**-2.272**	**0.042**
P4	-	-	4.99	7	5.16	12	-	-	-0.471	0.643	-1.665	0.118
M1	2.52	3	2.45	7	2.56	13	-1.26	0.245	-0.923	0.368	-	-
M2	-	-	5.96	6	5.97	7	-	-	-0.044	0.966	-	-

Values of t in **bold** are significant at $p \leq 0.10$

Values of t in **bold underline** are significant at $p \leq 0.05$

Table 4 (Unabridged): Ambergris Intra-Site: Student's t-Test comparing mean number of defects between all age groups

	Ambergris						Student's t-Test					
	Subadult				Adult							
	4-9 yrs		10-19 yrs		20+ yrs		4-9 yrs vs. 10-19yrs		10-19 yrs vs. Adult		4-9 yrs vs. Adult	
Tooth	**mean**	**N**	**mean**	**N**	**mean**	**N**	**t**	**p**	**t**	**p**	**t**	**p**
I1	3.00	3	2.42	7	2.50	8	0.556	0.593	-0.098	0.923	0.452	0.662
I2	3.00	4	2.25	8	2.77	9	**2.832**	**0.020**	-1.019	0.325	1.575	0.146
C	-	-	3.50	4	2.57	7	-0.755	0.495	1.715	0.120	-	-
LC	2.00	1	4.33	3	2.66	9	**-3.500**	**0.073**	**3.062**	**0.012**	-0.730	0.485
P3	-	-	2.43	7	1.80	10	-	-	1.619	0.126	-	-
P4	-	-	2.29	7	1.63	11	-	-	**1.902**	**0.075**	-	-
M1	3.00	3	2.14	7	1.85	13	1.594	0.150	0.827	0.419	**2.825**	**0.013**
M2	-	-	1.60	5	2.00	5	-	-	-1.000	0.347	-	-
M3	-	-	1.00	2	1.00	4	-	-	-	-	-	-

Values of t in **bold** are significant at $p \leq 0.10$

Values of t in **bold underline** are significant at $p \leq 0.05$

Table 6 (Unabridged): Actuncan Intra-Site: Student's t-Test comparing mean number of defects between all age groups.

	Actuncan						Student's t-Test					
	Subadult				Adult							
	4-9 yrs		10-19 yrs		20+ yrs		4-9 yrs vs. 10-19yrs		10-19 yrs vs. Adult		4-9 yrs vs. Adult	
Tooth	**mean**	**N**	**mean**	**N**	**mean**	**N**	**t**	**p**	**t**	**p**	**t**	**p**
I1	0.00	4	5.00	3	2.83	6	-	-	**<u>3.688</u>**	**<u>0.008</u>**	**<u>-6.385</u>**	**<u>0.000</u>**
I2	0.00	3	4.00	4	2.71	7	-	-	**<u>3.323</u>**	**<u>0.009</u>**	**<u>-7.016</u>**	**<u>0.000</u>**
C	-	-	4.50	2	3.20	5	**<u>-17.008</u>**	**<u>0.000</u>**	1.139	0.306	**<u>-4.824</u>**	**<u>0.001</u>**
LC	0.00	1	3.00	2	2.66	3	**-3.000**	**0.095**	0.293	0.789	**-3.098**	**0.053**
P3	-	-	3.83	6	1.75	8	-	-	**<u>6.419</u>**	**<u>0.000</u>**	-	-
P4	-	-	3.00	2	1.50	4	-	-	**<u>3.464</u>**	**<u>0.026</u>**	-	-
M1	0.00	5	2.50	2	2.50	4	-	-	-1.111	0.329	-1.111	0.329
M2	-	-	3.00	2	1.80	5	-	-	**<u>3.586</u>**	**<u>0.016</u>**	-	-
M3	-	-	3.00	1	1.75	4	-	-	2.236	0.111	-	-

Values of t in **bold** are significant at $p \leq 0.10$

Values of t in **<u>bold underline</u>** are significant at $p \leq 0.05$

Table 8 (Unabridged): Actuncan Intra-site: mean age at defect among all age groups

	Actuncan number of defects						Student's t-Test					
	Subadult				Adult							
	4-9 yrs		10-19 yrs		20+ yrs		4-9 yrs vs. 10-19yrs		10-19 yrs vs. Adult		4-9 yrs vs. Adult	
Tooth	**mean**	**N**	**mean**	**N**	**mean**	**N**	**t**	**p**	**t**	**p**	**t**	**p**
I1	2.00	1	5.00	3	2.83	6	-	-	**3.688**	**0.008**	-0.785	0.468
I2	2.00	1	3.80	5	2.71	7	**-3.740**	**0.021**	**2.851**	**0.017**	-0.884	0.411
C	-	-	4.50	2	3.20	5	-	-	1.139	0.306	-	-
LC	-	-	3.00	2	2.66	3	-	-	0.293	0.789	-	-
P3	-	-	3.83	6	1.88	9	-	-	**5.561**	**0.000**	-	-
P4	-	-	3.00	2	1.50	4	-	-	**3.464**	**0.026**	-	-
M1	1.50	2	2.50	2	2.00	4	-1.414	0.293	1.633	0.178	-1.633	0.178
M2	-	-	3.00	2	1.80	5	-	-	**3.586**	**0.016**	-	-

Values of t in **bold** are significant at $p \leq 0.10$

Values of t in **bold underline** are significant at $p \leq 0.05$

Table 13 (Unabridged): Ambergris and Actuncan Inter-site: comparing the mean age at defect between all age groups

	Ambergris						Actuncan						Students's t-Test					
	Subadult				Adult		Subadult				Adult							
	4-9 yrs		10-19 yrs		20+ yrs		4-9 yrs		10-19 yrs		20+ yrs		4-9 yrs		10-19 yrs		Adult	
Tooth	**mean**	**N**	**mean**	**N**	**mean**	**N**	**mean**	**N**	**mean**	**N**	**mean**	**N**	**t**	**p**	**t**	**p**	**t**	**p**
I1	2.52	3	3.17	7	3.26	8	2.99	1	3.18	3	2.75	6	-0.652	0.581	-0.09	0.932	1.685	0.118
I2	2.81	3	3.31	8	3.38	9	3.28	1	2.70	5	3.25	7	-0.453	0.695	**1.85**	**0.092**	0.468	0.647
C	-	-	4.17	4	4.30	7	-	-	3.37	2	3.90	5	-	-	1.42	0.23	1.207	0.225
LC	-	-	3.23	4	3.39	9	-	-	3.00	2	2.68	3	-	-	0.92	0.412	**4.538**	**0.001**
P3	-	-	4.02	6	4.53	13	-	-	4.35	6	4.58	9	-	-	-1.01	0.337	-0.212	0.835
P4	-	-	4.99	7	5.16	12	-	-	5.06	2	5.30	4	-	-	-0.15	0.882	-0.269	0.792
M1	2.12	2	2.45	7	2.56	13	5.15	2	2.73	2	2.61	4	**-3.822**	**0.062**	-1.76	0.121	-0.251	0.805
M2	-	-	5.96	6	5.97	7	-	-	6.15	2	6.25	5	-	-	-0.86	0.424	-1.510	0.162

Values of t in **bold** are significant at $p \leq 0.10$

Values of t in **bold underline** are significant at $p \leq 0.05$

Table 15 (Unabridged): Inter-site: Student's t-Test comparing the mean number of defects between all age groups

	Ambergris						Actuncan						Student's t-Test					
	Subadult				Adult		Subadult				Adult							
	4-9 yrs		10-19 yrs		20+ yrs		4-9 yrs		10-19 yrs		20+ yrs		4-9 yrs		10-19 yrs		Adult	
Tooth	**mean**	**N**	**mean**	**N**	**mean**	**N**	**mean**	**N**	**mean**	**N**	**mean**	**N**	**t**	**p**	**t**	**p**	**t**	**p**
I1	3.00	3	2.42	7	2.50	8	2.00	1	5.00	3	2.83	6	0.433	0.707	**<u>-3.382</u>**	**<u>0.010</u>**	-0.468	0.648
I2	3.00	4	2.25	8	2.77	9	2.00	1	3.80	5	2.71	7	1.732	0.225	-3.593	0.004	0.112	0.905
C	-	-	3.50	4	2.57	7	-	-	4.50	2	3.20	5	-	-	-1.886	0.132	-0.891	0.394
LC	2.00	1	3.75	4	2.66	9	0.00	1	3.00	2	2.66	3	-	-	0.667	0.541	0.000	1.000
P3	-	-	2.50	6	1.85	10	-	-	3.83	6	1.89	8	-	-	**<u>-2.902</u>**	**<u>0.016</u>**	-0.135	0.894
P4	-	-	2.28	7	1.58	11	-	-	3.00	2	1.50	4	-	-	-1.273	0.244	0.222	0.827
M1	3.00	2	2.14	7	1.85	13	1.50	2	2.50	2	2.00	4	**3.000**	**0.095**	-0.509	0.626	-0.437	0.668
M2	-	-	1.60	6	1.71	7	-	-	3.00	2	1.80	5	-	-	**<u>-3.416</u>**	**<u>0.019</u>**	-0.225	0.826

Values of t in **bold** are significant at $p \leq 0.10$

Values of t in **<u>bold underline</u>** are significant at $p \leq 0.05$

VITA

Nicholas Billstrand was born and raised in the South Suburbs of Chicago. He completed his Bachelor's degree in Anthropology with a focus in Bioarchaeology and Forensics from Southern Illinois University in Carbondale Illinois in 2011. He has and continues to hold positions with multiple CRM firms. He has been working nonstop since his career began in 2010 and continues to take over the world one day at a time.